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What an Engineer Should Know about Electricity

BY

ALBERT L. CLOUGH, E.E.

Also the Rules and Requirements of the Underwriters' International Electric Association, for the Installation of Electric Light and Power

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INTRODUCTION.

THE development and extension into practical use of the various electrical devices, have left extremely few buildings, whether factory, office building, or residence, unequipped, to a greater or less degree, with the modern time and labor saving and comfort increasing arrangements to which electricity seems specially adapted. Electric bells, gas lighting, and burglar alarms are found in most well equipped residences, and the incandescent light in not a few; while the applications in factories and public buildings of all kinds are far more various, including watchmen's clocks, incandescent and arc lights, temperature regulators, annunciators, automatic fire alarms, private telephones and telegraphs, and electric fans and elevators.

We have grown to depend upon these conveniences so implicitly that an instance of their failure is particularly annoying; yet it must be confessed that the liability of imperfect operation in most of them is still quite large, due in great part to the careless way in which many of them were installed in the period of hasty construction which elapsed, before electricity had become the indispensable reality which it is to-day.

The presence of some one able to remedy minor electrical troubles, and especially to tell whether electrical construction work is being, or has been, well done, is a very great advantage, and is capable of preventing much future trouble and financial loss.

The object of this book is to present plainly, and without the use of difficult technicalities or mathematics, to all who have to deal with electrical appliances, brief descriptions of their various forms, practical "pointers" on the troubles to which they are liable, and their remedies, as well as general instructions for doing simple construction work such as is often needed as a slight extension of an already established plant. It does not make any claim to cover the whole field of electrical construction, but presents some hints which it is hoped may be useful.

There is one matter which should be at the outset fully appreciated and always kept in mind, and that is, the necessity for the use of the best materials and the employment of the best workmen in order to secure the best results. This is true in electrical engineering as nowhere else. It is simply impossible to secure good, uninterrupted service, unless the conditions have been made favorable by the most thorough-going construction in every particular, however minute. *Electrical work cannot safely be slighted.*

The Fire Underwriters have done much in the direction of improved electrical engineering. Their rules for the installation of electrical apparatus in buildings which they approve are very excellent, and should be strictly followed by every one concerned with electric light or power work.

It will be noticed that the matter to be treated here has been placed under the two heads of *light current working* and *heavy current working*, a classification which it is believed will be useful. A few general considerations regarding electricity precede.

ALBERT L. CLOUGH.

ELECTRICITY FOR ENGINEERS.

GENERAL CONSIDERATIONS.

Source of Electricity. Electricity for its various uses is furnished by either the *battery* or the *dynamo machine*. In the case of the battery it is the result of chemical action, while in the case of the dynamo it is the result of the expenditure of mechanical power.

An electrical circuit is the continuous path of an electric current. For the current to flow, it must have what is called a complete or *closed circuit*. It must be a continuous path including the battery or dynamo, the wires, and all the devices to be operated. We may always start at any point in a circuit, and trace the path of the current entirely around back to the starting point. If we cannot do this there is a break somewhere, and the circuit is said to be open.

A conductor is any body that will form any part of a path or circuit for the current, and an *insulator* is one which will not form a path for it. The best conductors are the metals and carbon; while air, glass, porcelain, and rubber are among the best insulators.

Whenever the current passes a more or less number of times through a wire in the same direction about a piece of soft iron, the iron becomes a magnet as long as the current is flowing in the wire, but ceases to be a magnet when the current stops; indeed, the wire itself has all the

properties of a magnet, which the presence of the iron simply increases. The iron, with the wire round it, is called an *electro-magnet*, and will attract other iron held near it.

Heat is always produced throughout the circuit when the current is flowing, but especially when the current meets with a hindrance or resistance to its flow, as when it comes in its path to a rather poor conductor. The heating is then mostly produced at the points in the circuit where the poorer conductors are situated. For instance, the heat appears at the filament of an incandescent lamp rather than along the wires which feed it, owing to the fact that the filament, because of its very small size and the material of which it is composed, offers many times as much resistance to the current as does the whole length of wire leading to it.

VOLTS, AMPERES, AND OHMS. OHMS LAW.

WHILE it is unnecessary for one to have an extensive theoretical knowledge of electricity to successfully deal with electrical apparatus, a thorough knowledge of the practical units of electrical measurement is essential. The terms *volt*, *ampere*, and *ohm* are so constantly used by all electricians in describing and rating the various motors, dynamos, lamps, batteries, and other electrical machinery, that they should be perfectly clear to anyone who aims at an intelligent understanding of the devices with which he may meet.

In any electric circuit we have to consider three conditions. (1) The volume, strength, or intensity of the current ; (2) its tension or electromotive force (e. m. f.), which is the pressure that causes the current to flow ; and (3) the resistance of the circuit, which is the hindrance to

the current's flow. The current strength is measured in amperes, the pressure in volts, and the resistance in ohms.

If we know any two of these three facts concerning a particular circuit, we may find the third by a very simple formula. For instance: if we know the current passing to be a certain number of amperes, and the pressure that is forcing the current along to be a certain number of volts, and we wish to find how much resistance the circuit is offering to the current, we have only to divide the number of volts by the number of amperes. The result is the number of ohms.

And again, to know how many volts pressure it will take to drive a certain number of amperes of current through a circuit whose resistance is a certain number of ohms, we simply have to multiply the number of ohms by the number of amperes, the product being the required pressure in volts. Or, if we know how many volts pressure is being applied to a circuit, and how many ohms resistance it is offering, dividing the number of volts by the number of ohms will give us the number of amperes of current flowing.

The actions in an electric circuit are often compared with those in a system of city water distribution: the electrical pressure, or electromotive force corresponding to the head of the water, the electric current to the flowing of the water, and the electrical resistance to the friction of the piping and the contractions at the outlets. Sometimes it is helpful to bear this illustration in mind.

As an example of one of the foregoing rules, suppose we have a 110 volt incandescent lamp, that is, a lamp intended to be run at a pressure of 110 volts, and we know its resistance to be 200 ohms; how much current will pass through it when in use?

$110 \div 200 = .55$ amperes, is the correct answer.

The presence of an electric current means that there has been expended for its production a certain amount of energy or power, whether by the dissolving or burning of zinc in a battery or by the combustion of coal under a boiler. The heating of an incandescent lamp filament is nothing more or less than the return, in the same form, of a part of the energy or power which was given to the boiler as the heat of the burning coal, and which was used by the engine and dynamo in the production of the current; and the operating of a street car motor is simply the giving back of part of the mechanical power which was expended at the power house in running the dynamos that feed the circuit. The power in an electric circuit is measured in horse-power. The number of horse-power being given out is found by multiplying the pressure in volts by the current in amperes, and dividing the product by 746. If the product is left without dividing by 746, we have the power in watts, a unit which is much used in the rating of electric lamps, and sometimes even in stating the capacity of dynamos. One or two examples may be useful here.

A dynamo is delivering a current of 10 amperes at 2500 volts to some arc-lamps, how many horse-power is it delivering?

$$10 \times 2500 \div 746 = 33.5 \text{ HP (about)}; \text{ answer.}$$

An incandescent lamp is taking .55 amperes at 110 volts pressure, how many watts is the lamp consuming?

$$.55 \times 110 = 60.5 \text{ is the result.}$$

PART I.

LIGHT CURRENT WORKING.

THE BATTERY.

THE battery is indispensable to all branches of applied electricity in which small currents are used, as is the case in all kinds of signalling, gaslighting, and the like. A battery is an arrangement for producing available electricity from chemical action, and it always consists in practice of a plate of zinc, and a plate of some other metal or of carbon, both immersed in a chemical solution in a convenient jar. Each one of these combinations of the two plates, solution, and jar is generally called a *cell*, while the term battery is reserved for a number of cells connected one to the other. When a circuit is completed between the two plates in a cell, a current flows, due to an electromotive force or difference of electric pressure of from 1 to 2 volts which is set up between them: the zinc is dissolved and gradually disappears into the solution, while the solution is altered chemically in various ways.

Certain types of cells make use of two solutions in their operation, the two different fluids being kept from mixing by porous earthenware partitions. In such cases the solution surrounding the zinc is useful in attacking and dissolving it, while the other fluid acts to prevent the accumulation of gas bubbles upon the other plate which would otherwise produce *polarization*, or a checking of the battery's action. In certain cells there is a block of some material placed on the copper or carbon plate, or it

is surrounded by a paste, in order to prevent polarization; this being used instead of a second solution.

There is practically but one way of *connecting cells* to form a "battery." This is to connect, by wires, the zinc plate of one cell to the carbon or copper plate of the next, and so on; so that no matter how many cells one has, when joined in this way, there will be an unconnected zinc at one end of the series and an unconnected carbon or copper at the other end, and from these two free ends wires go to the instruments to be operated. Other methods of connection suitable for exceptional instances will be found in text books on the subject,

Of course a battery, like all other parts of a circuit, offers resistance to the current, and this fact should always be borne in mind in any calculations on the subject. The resistance which a cell offers may be roughly stated as from $\frac{1}{2}$ to 2 ohms, and depends largely upon the nature of the solution, and is larger as the plates are smaller and farther apart. The resistance of a battery of several cells is naturally the sum of the resistances of the separate cells, and its electromotive force is the sum of the electromotive force of the separate cells.

Example: —How much current will a battery of 6 cells force through an electromagnet of 5 ohms resistance, not counting the resistance of the connecting wires. The electromotive force of each cell is 1.5 volts and the resistance 1 ohm.

$6 \times 1.5 = 9.0$, or total electromotive force.
$6 \times 1 = 6.0$, or resistance of battery alone.
$6 + 5 = 11$, total resistance in circuit.
$\frac{9.0}{11} = .818$ amperes; answer.

KINDS OF BATTERIES.

Although there have been devised an almost endless variety of batteries, there are comparatively few much used, and with which one is likely to meet; these are

The Leclanché; and other sal-ammoniac cells.

Gravity and other blue vitriol cells.

Bichromate and other cells for occasional use.

The Leclanché Cell is one of the most important elements in the success of the modern "light current" applications of electricity. It is difficult to imagine how we could get along without it, as it operates nearly all the electric bells and other signals, does practically all the electric gaslighting, and forms a part of every telephone outfit; indeed, it is such a widely used and well known article as hardly to need description. In this battery an amalgamated [1] zinc rod and a carbon plate are employed, placed in a solution of sal-ammoniac. The sal-ammoniac acts upon or dissolves the zinc, while a mixture of black oxide of manganese and powdered coke placed about the carbon prevents polarization.

The Leclanché cell is made in two general forms, the *porous-cup* or *disque*, and the *prism* or *Gonda*. In the porous-cup form the black oxide of manganese and coke are kept in place about the carbon by a porous earthenware jar, and in the gonda the mixture is compressed into solid blocks, one of which is attached to either side of the carbon plate by rubber bands; of these two varieties the gonda is probably of the lowest resistance. Of late, cells have been considerably used in which the zinc, instead of being a rod, is in the form of a hollow cylinder

[1] The method of amalgamating or coating zinc with mercury is simply to clean the zinc with muriatic acid and then rub it with a few drops of metallic mercury.

surrounding the carbon and its depolarizing mixture, securing very low resistance. Even if the depolarizing mixture is not used at all and the cell constructed simply of the zinc and carbon plates in a sal-ammoniac solution, it works very well for ordinary purposes, and quite a variety of forms are made after this plan. All good cells of this class have glass jars with tightly fitting covers through which the zinc and carbon pass snugly, thereby preventing too rapid evaporation of the liquid.

It is always to be remembered that the Leclanché cell is only suitable for applications that require a rather small current intermittently; that is, for circuits which are kept open most of the time, and in which the apparatus acts when the circuit is closed, as is the case with electric bells, gaslighting, and the like. It is distinctly not applicable to closed circuit work.

The fact that in this cell the consumption of zinc and the chemical change of the solution occur only when current is being generated and not when the circuit is open, is one of the great advantages, and under ordinarily good circumstances it should run for years without any considerable amount of care. The quickness with which it will "run down" and require attention depends mostly on how long, in all, the circuit has been closed, so that a few hours continuous closure might exhaust it as much as years of ordinary service. The thing to be avoided is accidentally allowing the circuit to be closed for a long time. Directions for "*setting up*" usually accompany these cells, but a few points not always mentioned may be useful. One should always be sure that there is no possibility of the zinc coming into contact with the carbon or its attachments in the liquid, as this would run the cell down rapidly, and one should see that the rim of the jar and the head of the carbon are completely covered with a

thin layer of paraffine wax, and that the jar is always kept between one-half and two-thirds full of solution. It is a very common mistake to fill the jars too full: in which case, if the paraffine rim is not perfect, the solution is almost sure to crawl up the glass and reach the connections of the carbon and zinc, corroding them, sometimes to the extent of breaking the circuit, as well as dampening the shelf upon which the cells rest, thus causing an excape of current and a gradual exhaustion of the battery. In locating a battery intended for permanent use, it is best to place it where it is neither too hot and dry nor very damp, as rapid evaporation of the liquid in the first instance, and corrosion of the connections in the latter, are apt to follow. It is bad practice, on the whole, to place it in a furnace-heated basement, for the air is too hot and dry in the winter and too damp in the summer. About the best place seems to be on a shelf in a closet near the middle of the ground floor of the building, as it is very accessible and at a nearly even temperature. Of course a battery should never be located where there is any possibility of a freezing temperature being reached.

In spite of every precaution, the circuit of a battery will sometimes become closed for a long enough time to exhaust it. If the zincs are seen to be very much eaten away and the carbon and its attachments covered with crystals, and if there is a smell of ammonia noticeable about the cells, one may be pretty sure that this has happened, and that the battery will probably have to be removed. The first thing to be done is to disconnect from the battery the circuit on which the trouble has taken place, and sometimes, if the exhaustion has not gone too far, the battery will, if left to itself for a few days, recover almost its original strength. If, however, it does not, the cells should be taken down and taken

apart, all the parts washed, and the crystals scraped off; the zincs, if not too much eaten away should be amalgamated, and a new solution made of the best sal-ammoniac. The carbons have not been injured, but the gondas or the contents of the porous cups have been rendered useless. However, these can be made almost as good as ever, and the expense of buying new ones avoided if they are treated in the following way. Put the cells together again, having them still joined in series; replace the sal-ammoniac solution with water, and to each jar add half a fluid ounce of sulphuric acid; then connect the battery to a dynamo circuit so that the current enters at the "free" carbon pole and passes out at the "free" zinc. It will generally be necessary to put quite a large amount of resistance, either of wire or of incandescent lamps, in circuit with the cells, so that the current will not be too strong. Have the current pass in such a direction, and of such a strength, that gas bubbles will be given off pretty freely at the zincs, but very slightly at the carbons; and pass the current for six or eight hours.

The important point is to have the current in the right direction; that is, so that the gas will be mostly given off at the zincs. Of course the current of an alternating dynamo would not do for the purpose. After the cells have been so treated they are ready for the fresh sal-ammoniac solution and newly amalgamated zincs, and should be found to be as strong as ever.

I might say here that sal-ammoniac, although harmless to the person or to the clothes, attacks copper or brass very vigorously, so that a single drop spattered upon a wire is likely to eat it off completely and open the circuit, a trouble which is very annoying and difficult to locate.

Gravity and other Blue Vitriol Cells. — Practically all closed circuit working employs cells of this class. By

closed circuit working is meant the use of circuits containing devices which are operated upon the breaking of the current which is kept continually flowing. This includes local commercial telegraph lines, the police and fire alarms, district telegraph, some burglar alarm systems, etc. These cells always consist of a zinc plate in a solution of zinc sulphate or white vitriol, and a copper plate in a solution of copper sulphate or blue vitriol. The zinc sulphate acts upon zinc and gradually dissolves it, while the copper sulphate about the copper prevents polarization (q.v.). The two solutions are sometimes kept from mixing by the use of a porous cup, as in the Daniels cell, or are kept apart by gravity, as in the gravity cell. The gravity cell consists of a large cylindrical jar on the bottom of which is placed a +, made of sheet copper stood on edge, and provided with an insulated wire leading up and out of the jar; from the edge of the jar is suspended the zinc in a horizontal position near the top of the vessel. The zinc may be either in the form of a wheel or any shape giving large surface. The copper sulphate solution being heavier than the zinc sulphate solution, sinks to the bottom of the vessel, forming a layer about the copper plate and preventing polarization, and leaving the upper part of the jar about the zinc filled with the lighter zinc solution. The best way of "setting up" the gravity cell is to place at the bottom of the jar around the copper about one pound of blue vitriol, then to add one ounce or so of white vitriol, and finally to fill the jar with water sufficient to cover the zinc. The solutions should separate, and the cell be ready for use in a few hours, especially if it be short-circuited; that is, if the wire from the copper be attached to the zinc. If the white vitriol is not at hand, the cell may be started by simply supplying the blue vitriol and water, and short-circuiting the cell. The solutions will separate in a day or two.

In maintaining the gravity cell the line of separation of the two solutions should be kept an inch or two above the copper, and in no case should it approach the zinc. If one has any considerable number of these cells to take care of, it is well to be provided with a good-sized battery syringe and to keep a saturated solution of blue vitriol on hand. It is desirable, too, to have a hydrometer — a little floating instrument for determining the strength or density of the zinc solution. It is the tendency of the zinc solution to become too strong or dense, after the cell has been working some time, in which case one should remove some of it by means of the syringe and replace it with water until the hydrometer, when floated in the solution, stands at about 1020 degrees. If this were not done, the zinc solution might become denser than the copper solution, which would result in the two solutions changing places and stopping the action of the cell. There should always be crystals of blue vitriol at the bottom of the jar to keep the blue solution saturated; but in case all the crystals become dissolved and the blue solution gets low, it can be replenished by means of the syringe without causing the liquids to mix, and a fresh supply of crystals may be dropped into the jar. Once in a while the jars should be thoroughly cleaned out and set up anew, but this is only necessary at long intervals. The zinc in this class of cells never requires to be amalgamated.

The bichromate cell is very little used for purposes that require continuous service; it is mostly employed for occasional uses, as the operating of medical batteries and experimental apparatus of all kinds. This cell makes use of the zinc and carbon plates in a solution for which the following is a recipe: — Add pulverized bichromate of soda to warm water until it will dissolve no more; allow it to cool, and then add one-fifth of its volume of common

sulphuric acid. When the cell is set up with this solution its electromotive force is quite high, and its resistance fairly low, so that it will give quite a large current if it is not required for a long time. The zincs, however, require to be frequently amalgamated, and must not be left in the solution when the cell is not in use, as they rapidly dissolve even when the circuit is open. The soaking of the carbons in melted paraffine to prevent the possibility of the solutions reaching the connections is also an important precaution to be observed. For further particulars in regard to cells of all kinds, the reader is referred to an excellent work entitled "Electric Batteries," by Alfred Niaudet, which gives full description of all the various types.

CIRCUITS.

As is well known, copper wires of various sizes are employed in electrical work, the numbers used in this country to designate them being those of the American, or Brown & Sharpe, wire gauge.

The tables published by the various wire manufacturers contain the diameters, sectional areas, the resistance in ohms per thousand feet, feet per ohm, ohms per pound, and feet per pound of the sizes designated by the different gauge numbers. These tables may be obtained of the manufacturers upon application, are very useful, and should be in possession of every one having to do with electrical apparatus. It may be well to be reminded that of course the resistance of a circuit is proportional to its length, — a circuit twice as long as another composed of the same sized wire offering twice as much resistance; and also that a circuit of a certain gauged wire possesses one-half the resistance of one of the same length formed of wire having twice the sectional area of the first. The sizes most used

for "light current working" in buildings have been Nos 18 and 16; but some of the best electricians are now using 16 and even 14, as being larger and less likely to be broken. No. 18 or 16 wire which has been insulated by winding it with a double layer of cotton thread and then soaking it in melted paraffine is called annunciator wire, and that which has a layer of braiding over the winding is generally spoken of as office wire. These forms of insulation are the ones almost universally used for light current work, and, although good enough when kept dry, should not be depended upon for use in damp places, as the moisture works through the covering, causing an escape of current to take place which gradually exhausts the battery and corrodes the wire; neither should they be employed where there are corrosive fumes of any sort as they do not protect the copper from being acted upon. In such cases as these, one should see that there are used wires of the so-called "weather-proof" variety, which have coverings treated with water-proofing and fire-proofing compounds. Some of the most careful and thorough electricians are using these wires very largely in their best contracts. Whenever the wire is likely to be subjected to hard usage it should have a covering not likely to be worn through or rubbed off. In this respect the braided is far better than the wound covering, and the weather-proof insulation superior to either. A soft rubber tube slipped over the wire at points where it is especially liable to injury is a great protection, and winding it with the adhesive insulating tape, especially made for the purpose, has much the same effect. Where wires have to be connected with one another, joints necessarily occur. They should be avoided as far as possible, and one can by a little forethought and planning arrange so that there will be very few required. Formerly people seemed to think

hat any sort of a twisted joint between two wires was a fficiently good electrical connection between them for se of light current circuits; but it is beginning to be seen hat this is the "haste makes waste" policy, and that relessly made joints are almost sure to cause future nnoyance and the waste of much time in locating oubles. Wherever joints must occur they should be ade of the regular form of a lineman's joint in an over-ead wire; the wires should be scraped bright and twisted ghtly together with a pair of plyers, then soldered, care-lly cleaned of any remains of acid, and covered thor-ughly with adhesive tape. One should especially see hat these precautions are taken with joints that are to be oncealed and difficult of access. At this point it may e well to speak of the great importance of having only he best connections or contacts in the circuit, so that they ay add as little resistance as possible. As every one nows, the connections with almost all kinds of electrical paratus are made by means of binding-posts — screws hich clamp and hold the circuit wires. The wires to be nnected to the instruments should always be scraped right, and should be placed in the binding-posts so as to e least liable to work loose; the surfaces of the screws hich clamp the wires ought to be cleaned and should be et up tightly, but not so tightly, of course, as to cut off he wire. It is really remarkable how often trouble is pro-uced by loose or dirty contacts, and one should ever be pon the watch for them.

The method of supporting the wires is a matter of im-ortance; and I cannot refrain from saying a word here gainst the double pointed tack, or staple, which has been o much and so injudiciously used for fastening wires in osition upon wood-work. Double pointed tacks in care-ss hands are a fruitful cause of trouble.

Used in damp places, and driven too hard, they cu through the insulation of the wire, increasing the escap of the current, or sometimes even cutting off the wire, i which case the remaining insulation holds the severe ends very close together and prevents the defect fro being readily noticed. Sometimes, in order to save time more than one wire is held under the same tack, the re sult being that a connection is often formed between tw or more of the wires and a trouble caused which is ver tedious to locate. It is safe to say that staples shoul never be used except upon dry wood-work, and then th same staple should never hold but one wire. It is fa better to see that they are not used at all, and to insis upon the use of the far safer and neater cleat. Thes cleats are made of sizes suitable for holding any numbe of wires, and may be used with advantage on wood-wor or on plastering. They are strips of hard wood intende to be fastened in place by screws, and are crossed b grooves in which the wires fit tightly when the groove side is placed against the ceiling or wood-work and th screws set up, the wires being held firmly in place an prevented from slipping. They have the advantage o keeping the wires at an equal distance apart at all points thus improving their appearance, besides removing th danger of cutting the insulating covering which attend the use of tacks. If the wire is drawn taut betwee the cleats and all kinks smoothed out of it, and if th cleats are placed carefully in line and set up tightly, winc ing the wire once round those cleats upon which the mos strain comes, a good-looking set of " lines " is the result but cleat work carelessly done, with the wires sagging an the cleats out of line, is an eyesore to every electrician In running circuits in cellars and other damp places, it i sometimes best to use small porcelain knobs, screwe

the plaster or beams, to which the lines are attached "tie wires" (short pieces of wire which are passed ound the knob and twisted about the wire to be sup- rted in the manner used on overhead lines). The obs hold the circuit wires from touching the wood or her material over which they pass, and afford really ite good insulation in unfavorable places. So far I ve spoken especially of wiring which is in sight — run ng walls or ceilings — and have not referred to concealed ring, which, however, is even more often met with; in- ed, is almost always found in dwellings and fine build- gs of all kinds. Concealed wiring, if done at that stage the construction of a building just before the lathing begun, is not difficult, as the spaces between the floors d walls are easily gotten at, and the wires may be ated or tacked to the timbers without trouble and ought out wherever wanted, the chief precaution being place them where they will be least likely to be dis- rbed in any way by the workman in putting down floors lathing; but to successfully conceal the wiring in a ilding already finished, without taking up the floors very objectional proceeding), is a rather troublesome tter. Each wire has to be pushed through a small nlet-hole into the space between the floor or walls, and en worked about until it can be caught and "fished t" through another small hole at the point where it is nted. Sometimes it takes a great deal of time and tience to do this, and when done there is always an certainty as to whether the wire lies where it will give od service.

It is plain that in this matter of concealed wiring the sadvantage is that one cannot get at it easily to locate d remedy troubles, and this has caused the extensive e of the *conduit* system. This excellent system consists

of tubes made of water and fire proof insulating materia which are placed in the building before the lathing an flooring has been done; they are fixed to the timbers, an are run wherever circuits are called for. It is so arrange that wires may be drawn into these tubes, and it is thus very easy matter to replace one at any time in case causes trouble. In many of the finest modern building all wires, for whatever purpose, are placed in these con duits, the slight likelihood of troubles occurring, and th ease of making repairs in case they do, more than makin up for the increased cost.

The course which a current should take to reach an desired point ought to be carefully planned out before an work is done upon it. The wires, if exposed, should ru where they are least likely to be interfered with in any way lest they should be loosened, broken, or stripped of thei insulation; for instance, they should be fastened flat t beams or ceilings, rather than pass from beam to bear through the air, and should be entirely out of ordinar reach. They should avoid as much as possible dam rooms, and, whether concealed or exposed, should kee carefully away from pipes of all kinds, and from othe wires, to avoid the chances of accidental connections; an last, but not least, other things being equal, the shortes way is the best, as less wire is needed and less resistanc added to the circuit.

This is all I shall say concerning "light current" cir cuits in general. More, however, will be said of ther when speaking of the special "light current" applications and I will now go on to a brief statement of some point relative to electric bells.

ELECTRIC BELLS.

Of all electrical devices the vibrating electric bell is, believe, the most familiar, and certainly is one of the ost useful. So familiar is it, indeed, that a description almost unnecessary. I will explain it briefly, however, by reference to Fig. 1, in which *M* is the electromagnet, and *A* its soft iron rmature which it is capable of tracting (p. 3).

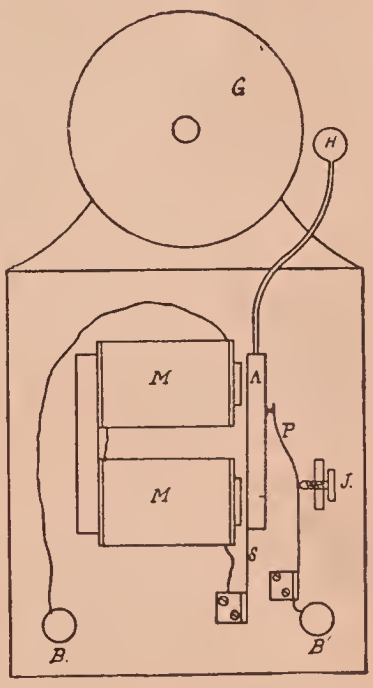


Fig 1.

The armature is provided with a ammer, *H*, and is supported by ne spring, *S*, which always keeps it ressed back lightly against another pring, *P*, thus holding the hamer a short distance away from ne gong, *G*. The circuit enters t the binding-post, *B*, passes hrough the coils of the electroagnet, then to the spring, *S*, p the armature, thence to the platinum-tipped spring, *P*, nd passes out at binding-post, *B*.

Now, when the two binding-posts are connected with a attery, the electromagnet attracts its armature, causing ne hammer to strike the gong a blow, and at the same me causing the armature and the spring, *P*, to part, thus reaking the circuit. As soon as the circuit is broken the agnet loses its power, and the armature returns to its riginal position, closing the circuit again. This action is ept up as long as the battery is applied, the bell giving continuous ring.

In choosing electric bells, one will find it of advantage

to use those which have covers fitting as tightly as possible, in order to prevent the entrance of dust or insects, and to employ only those which have all their parts fastened to an iron frame, so that they may be kept in the same position relatively to each other.

If the parts are fastened to a wooden back, there is likely to be trouble from the warping due to dampness. The points which make contact between the armature and spring should be of genuine platinum to insure a good connection, as it is much less likely than any other metal to become dirty or corroded. It is important in all bells to have an arrangement for changing the position of the spring upon which the armature is carried, so that the armature will rest nearer or farther from the magnet; and it is also important to have a screw (represented at *J* in the figure) to move the spring, *P*, to or from the magnet.

PUSH-BUTTONS.

Besides the bell itself, the push-button is perhaps the next important part of a bell circuit. It is, of course, the part at which the circuit is closed and the bell caused to ring. The most common form of push-button is merely a round piece of wood or hard rubber, having two thin brass pieces fastened to it by two of their ends, the other two ends overlapping but not touching. They are made to touch by pressing upon a small knob. The circuit wires are each fastened to one of the brass strips, and a tight cover screws down over them. Push-buttons are made of a great variety of forms and materials; most often they are intended to be screwed to walls, but sometimes to be attached to flexible conductors for convenience in moving them about. The principle of them all is the same, — the closing of the circuit by the bringing together of two con-

tact springs by pressure. The best push-buttons are those in which the contact pieces are quite springy, so that a slightly rubbing contact is the result when they are brought together, which keeps the connecting surfaces bright, and makes the closing of the circuit more certain. Buttons in which the contact pieces are unyielding are much less sure, as the contact surfaces tend to become dirty. All buttons, but especially those intended for out-door use, are much better when made with hard rubber backs and bronze covers than when made of wood, as the wood is likely to warp and crack by the action of the weather, allowing dampness to enter which corrodes the contacts. The screws which serve to attach the circuit wires to the contact pieces should be of good size, so that they will bear being set up tightly, thus making sure of good contacts.

ELECTRIC BELL CIRCUITS.

THE circuit for ringing a single electric bell from a single point is of the simplest description. Fig. 2.

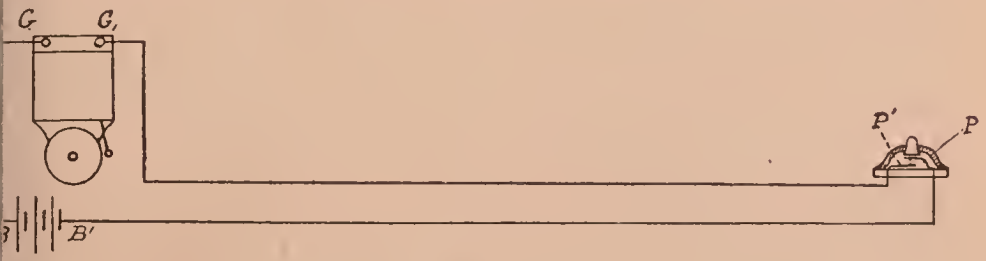


Fig. 2.

Starting at *P*, Fig. 2, one of the springs of the push-button, the circuit passes to *B'*, one of the battery terminals, through the battery, out at *B*, thence to the bell terminal *G*, out at *G'*, and then passes to the other contact

spring, P', of the press-button. The circuit is thus closed except at the button between P' and P, and a closure here will immediately set the bell ringing.

The arrangement for ringing more than one bell from the same point is represented by Fig. 3, and will explain itself. One should never try to ring several bells from the same button by connecting the bells in series; that is, arranging them as one would several cells to form a battery, for in this case, the bells being in the same circuit, and having the same current passing through them all, trouble would be caused by the fact that each bell would break the circuit for all the others, producing

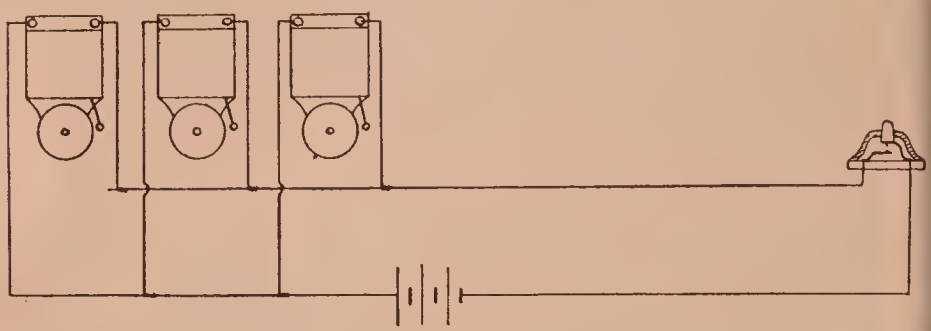


Fig. 3.

very irregular and uncertain ringing. For ringing the same bell from several stations the connections are as follows: — (Fig. 4) where C is the battery, B the bell which is to be rung from a number of different points, P^1, P^2, and P^3 push-buttons located at various places, and A^1, A^2, and A^3 annunciator drops placed near the bell to show which of the buttons causes the bell to ring. These annunciator drops are necessary when a great many buttons are connected to one bell, as is the case in hotels, etc., but may be dispensed with when the number of buttons is small. The kind most frequently met with is the "Gravity Drop," which consists of a small electromagnet placed in

he circuit of the button from which it is intended to be perated. This magnet has an armature which normally holds up and out of view a small tablet, upon which is the number or name corresponding to the button. When, however, the circuit is closed at the button, the armature of the magnet is attracted, allowing the tablet to fall into view; at the same time the bell rings, and it is at once known that a call has come from a certain definite point.

A large number of these drops placed in an ornamental frame and surmounted by a bell are found in almost every hotel and public building. The annunciators of different

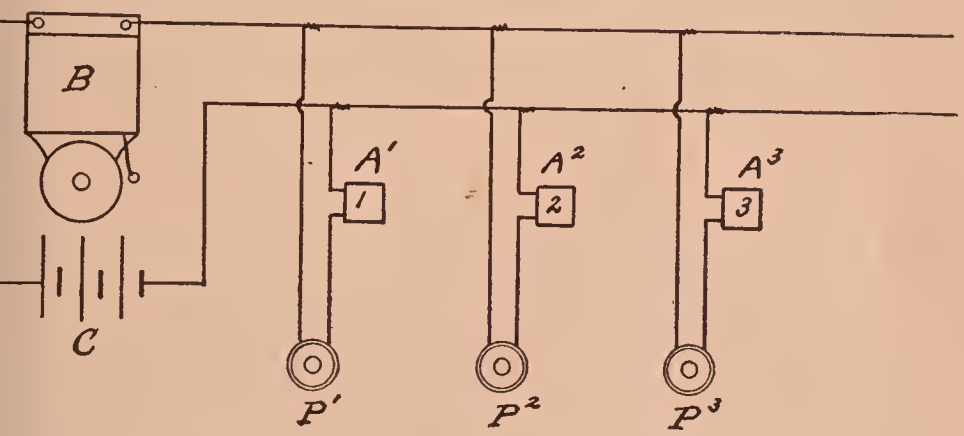


Fig. 4.

manufacturers differ so much in the details of their construction that it is difficult to give any general instructions concerning them. The main point, however, is to keep the drops in correct adjustment, so that they will be sure to fall when they should, but not to fall from any accidental jar or vibration to which they may be subjected.

What every one wishes to know is what to do to a bell when it will not ring. First take a look at the battery and see whether it has been run down or not (p. 11). If, as will probably be the case, it has not, and is still in good condition, one should examine the circuits carefully

throughout, looking for a broken wire, one cut off by a too-firmly driven staple, or one eaten off by moisture or a chance drop of sal-ammoniac. The firmness and cleanness of the contacts at the binding-posts of the battery and bell and at the screw connections of the button should be looked to, and the contact points in the button, and the contacts between armature and spring in the bell, made bright, if need be, by the use of a thin flat file. One should be on a watch for a contact between the two wires of the circuit between the battery and bell, as this would prevent the bell from ringing by stealing the current away from it when the button was pressed. The trouble is most frequently in the adjustment of the parts of the bell, and it becomes necessary to readjust them, which may be done in most bells in some such way as this: —

By bending the hammer or moving the magnets, arrange matters so that the gong will receive a blow just as the armature is about to strike the ends of the magnet; then, by moving the screw generally provided for the purpose, adjust the armature so that it naturally rests so as to hold the hammer perhaps $\frac{1}{4}$ inch from the gong. Now adjust the contact spring, by its screw, so that it will follow the action of the armature through a part of its stroke; see that everything is clean and tight, and your bell ought to ring. Of course bells vary so much in their construction that directions cannot be given which always apply.

If, instead of finding the battery all right, it is found to have been exhausted, it is probably due to there having been a permanent closing of the circuit, not complete enough perhaps to keep the bell ringing, as this would be immediately noticed, but sufficient to injure the battery. A double-pointed tack driven tightly over both wires may be to blame; the insulation of the wires may have been

worn off over a pipe, or any such accident may have happened. The permanent closing at the button by the sticking together of the contact springs may take place, but it is detected by the continuous ringing of the bell before the battery has been harmed.

It is best to see that bells are put up with the gong down, as they work much better in this position than when the box is below; and it is worth while to plan with some care their locations, so that they will be heard distinctly where it is desired they should be, but not disturb those not concerned with them.

The use of bells of different tones, of the cow-bell and sleigh-bell shapes and the "buzzer" form, is of advantage where many are used, as it prevents much confusion.

BURGLAR AND FIRE ALARMS.

MOST of the Burglar Alarm and Automatic Fire Alarm systems consist of the electric bell and annunciator system applied to these special purposes, and having the closing of the circuit accomplished automatically instead of by means of the common press-button.

The ordinary burglar alarm makes use of circuit closing devices which act when any attempt is made to open the doors or windows. The closing of the circuit rings a bell, of course, and locates the point where the entrance is being made by throwing the appropriate annunciator drop.

In the automatic fire alarm system the circuit is closed when the temperature of any part of the building to be protected rises above a certain dangerous point, 120° F. or so. The melting of a fusible metal may be made use of to allow two contact springs to come together, which

it ordinarily holds apart, or the circuit may be completed by the expansion of metals or liquids which force metallic connections together when a certain degree of heat is reached. If a building is thoroughly equipped with these arrangements for automatically sending in an alarm of fire, it is really a great safeguard.

To these two applications of electricity most of the remarks concerning electric bell work apply; but one should not fail to make frequent tests of the arrangements by actually operating them as they would be operated in practice, to be sure that they would work properly in case the occasion for their action should arise.

ELECTRIC GAS-LIGHTING.

I COME now to speak rather briefly of the very important application of electricity to the lighting of gas, which has become a necessity in almost all dwellings of any pretentions as well as in office buildings and other public places. Besides being a great convenience, it does away with the use of matches, and largely reduces the fire risk. Gas is lighted electrically by three different methods: the Pendent System, Automatic System, and the Multiple System.

The Pendent system is by far the most frequently used, and is so called from the fact that the gas is lighted by pulling a pendent chain connected with the burner. The arrangements for pendent gas lighting are very simple.

A battery (*B*) of five or six Leclanché cells is required, one pole of which, *R*, is connected to the main gas-pipe by a soldered contact; the other pole is connected to the spark coil, *S*, and from this a wire leads to the distrib-

ıting board, *D*, from which wires branch off to the various burners, one of which is represented at *G*.

Each wire going to the burner is connected to a small collar placed around the gas-tip and which is insulated

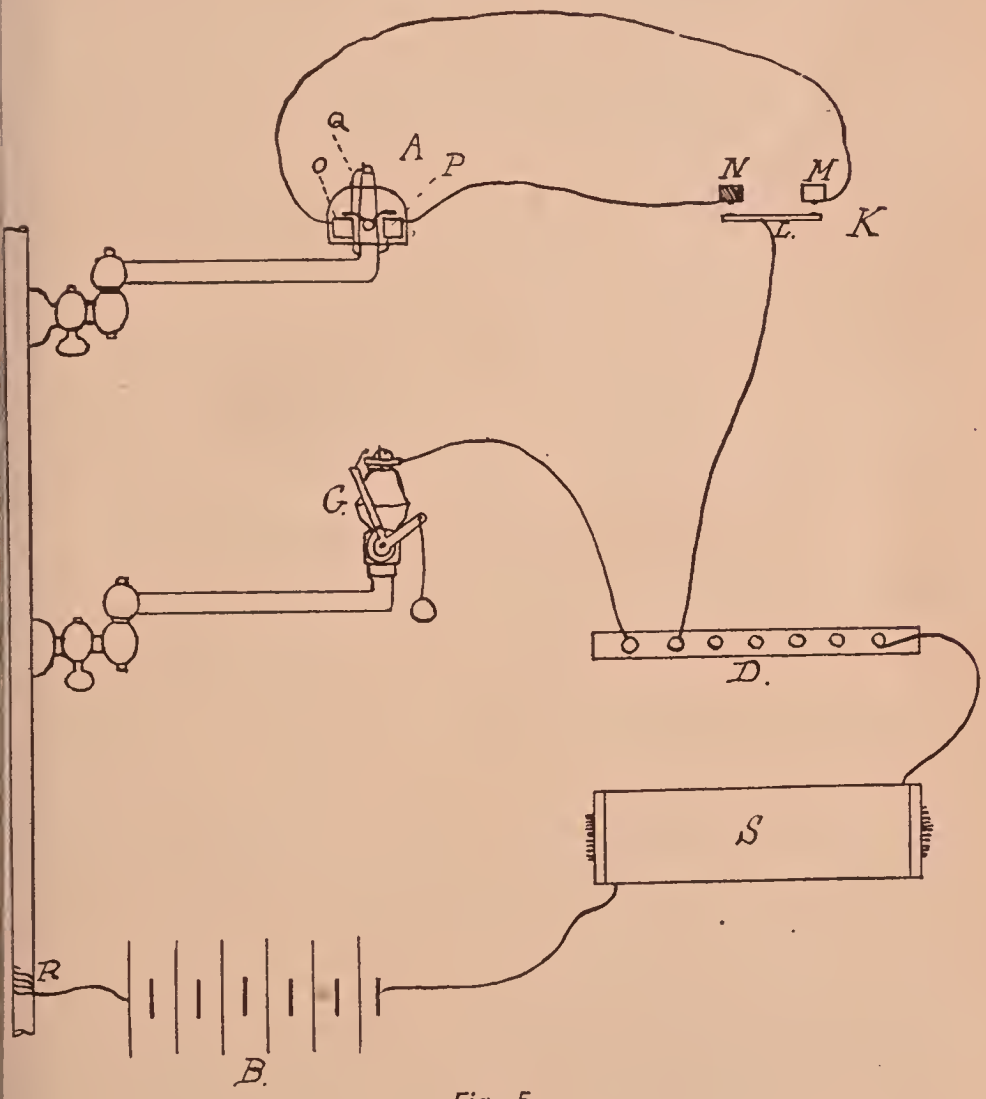


Fig. 5.

from the fixture by asbestos. Each collar has a little wire contact point placed close to the gas-slit, at which the igniting spark is produced. It is plain from the figure that it is only necessary to connect the insulated collar of a burner with some part in contact with the fixture in order

to close the circuit through battery, spark coil, wiring, and piping.

The "spark coil" is simply an electromagnet wound with a few turns of large insulated wire and with its core made of a bundle of fine soft iron wires. The closing of the circuit through it of course magnetizes it to a high degree, and the breaking of the circuit at the burner contacts causes the spark that does the lighting of the gas by discharging its magnetism.

The pendent burner is a burner having pivoted to it an arm which is worked by the chain. This arm carries a spring wire, which makes contact with the wire upon the insulated collar when the chain is pulled, and then snaps off again, making and then breaking the circuit, charging and discharging the spark coil, and producing a spark in line with the gas-slit. There is a spring which acts against the pull upon the chain, keeping the contacts normally separated. A pawl on the arm advances by one tooth, at each pull of the chain, an eight-tooth ratchet wheel which carries the four-way gas-cock, so that gas is alternately turned on and off the burner.

Sometimes the burners are made so that the pulling of the chain simply makes the spark, thus requiring the gas to be turned on in the ordinary way.

Ordinarily the pendent system works very well, giving very little annoyance and proving a great convenience, but there are certain points which sometimes give trouble. Owing to the necessity of using an open circuit battery for this work, so that the attention required shall be almost nothing, a permanent accidental closing of the circuit is especially to be avoided, as it means the ruin of the battery and the annoyance of having the gas-lighting system useless until the battery can be replaced. It is a great nuisance to have to descend to the use of matches throughout a

uilding when the gas for any reason fails to light electri-ally. There are devices on the market, however, which utomatically open the circuit and protect the battery upon ne formation of a permanent closed circuit, and one of nese should be used on all gas-lighting systems.

It is the sticking together of the contact points of the urners that is the most frequent cause of a permanent losed circuit; and one should examine each burner to nake sure that this cannot happen, bending the moving pring wire contact, if need be, so that there is no possi-ility of its catching upon the contact on the collar.

The wires running along the fixtures to the burners ometimes accidentally become connected to the piping, y rubbing upon some sharp part, which wears away their nsulation, and produces the same trouble. This is espe-ially likely to be the case where the wires run inside the asing of the fixtures, unless the best of wire is used, hav-ng as an extra insulation a very small rubber tube slipped ver its whole length.

The best fixture wires have several distinct coverings of otton and an inner winding of silk, and are of colors to natch different colored fixtures.

It is best, however, to avoid the ones covered with me-allic bronzing, as it may cause "leaks."

At the point where the wire goes up to the burner, it is well to slip over it a short piece of glass tubing, as with-out this precaution the insulation sometimes takes fire, burning down to the fixture and forming a contact between the wire and pipe, with the usual effect of permanently closing the circuit.

Joints in movable wall brackets are frequently the cause of wearing through of the insulation of the wire, unless sufficient slack is left at these points; and the rosettes through which the wires have to pass in coming out of the walls to the fixtures sometimes cut the covering.

It is, of course, more important in gas lighting than in any other light current work to keep as far as possible away from all pipes, or other metallic connections to ground; and in all parts of the circuit, where practicable, concealed work should be done with this fact in mind.

One should see that a separate wire is run from the distributing board to each chandelier and to each group of three or four brackets. It is easy then to locate and disconnect any wires upon which trouble occurs, without affecting the others. It is too often the case, however, that this matter is slighted, and only a few wires run for a large number of burners, a great many branches to various points being taken off the same wire, often at places between floors or in walls which it is extremely difficult to reach.

If any trouble occurs anywhere in a building wired in this way, it is likely that a large part of the burners will have to be thrown out of use.

In testing to find upon which of the wires leading from the distributing board the permanent closed circuit is located, it is best to disconnect all the wires, and then, supposing the battery to be of its usual strength, to touch the wires one by one to the distributing strip, the one which gives a spark being the defective one.

This should, of course, not be connected again until the trouble has been remedied.

If it is found that certain burners fail to give a proper spark when operated, it may be because the contact points have become corroded, or covered with soot from the flame; they should be cleaned with a small file and the collar rotated a little so that the point will not be exactly in line with the gas-slit.

Incandescent lights are now being very largely applied to gas fixtures, and gas-tight insulating couplings are used to disconnect the fixtures electrically from the piping,

in accordance with the Underwriters' Rules, making it impossible to use the ordinary form of gas-lighting circuit which utilizes the pipe as the return to the battery. It is necessary, therefore, to disconnect the pole of the gas-lighting battery from the gas-pipe, and to run instead wires from it to the various fixtures.

Under no circumstances should the insulating couplings, which the electric lights demand, be bridged over by wire in order to make the gas lighting work in its usual form, as this thwarts the purpose for which the couplings were used, and creates a certain amount of danger from fire. Indeed, electric gas lighting had better not be used on fixtures to which incandescent lights are attached.

The *automatic system* is used for lighting and extinguishing burners that are out of reach or at a distance. The arrangement is as follows: (Fig. 5), in which *A* is the automatic burner, and *K* the key which controls it. From the distributing board, *D*, is run a wire to one contact point, *L*, of the key, *K*. From the two contact points, *M* and *N*, wires are run to the burner, the wire from *M* going through the small electromagnet, *O*, which is arranged to turn on the gas through the vibrating contact, *Q*, which is placed close to the gas-slit, and at which the spark is produced, and thence to the fixture. The wire from *N* passes through an electromagnet, *P*, arranged to turn off the gas, and thence to the fixture. The contact *M* is forced against the contact *L* when the white button of the key is pressed, operating magnet *O* and vibrator *Q*, and turning on and lighting the gas. When the black button is pressed, contacts *N* and *L* are forced together, operating the magnet *P*, and shutting off the gas.

The same automatic burner may be operated from more than one point by adding several keys, the contacts of which are connected with the wires from the corresponding points of key, *K*, by branch wires.

It is better to place an automatic burner where its light can be seen from the keys which are to operate it, as sometimes, when not working properly, the burner may turn on the gas without lighting it, allowing it to escape without immediate detection if the burner's light is invisible from the key.

Automatic burners are especially useful for lighting and extinguishing the gas at the foot of a flight of stairs from the floor above, or the opposite; but their general use is not so satisfactory as that of pendent burners, as they are expensive and more likely to get out of order. The *multiple system* of gas lighting is largely used to light a number of burners simultaneously in halls, churches, or other large buildings. The burners for this system are made with highly insulated porcelain collars, each burner being provided with two contact points secured to the porcelain, one on either side of the gas-slit and separated from one another a small fraction of an inch. The source of the electricity for doing the lighting is a small "static" machine operated by hand, and producing sparks similar to the ones seen to jump from moving belts. The burners are connected together in "series" by bare copper wires run upon porcelain knobs to secure good insulation. The current, in order to traverse the whole circuit, has in turn to jump across the gas-slit of each burner. When the lighting is to be done the gas is turned on and the machine connected to the circuit; the spark produced at each burner ignites the gas. In damp weather it is not always easy to secure a good spark, as the machine is not likely to work especially well. The discharge of the machine, too, will sometimes leak around a burner, instead of sparking across between its contacts, when the insulation is defective from dampness or other cause.

PART II.

HEAVY CURRENT WORKING.

By "heavy current" applications of electricity is here meant the uses of the electric current for lighting as a motive power, and for any other purpose requiring a large quantity of energy in the form of electricity. Absolutely essential to these applications is the dynamo machine as a cheap and convenient means of generating the requisite current; indeed, without it, or something else equally good, the "heavy current" applications would be impossible, owing to the impracticability and great expense of using a battery to furnish the current.

It must be remembered that energy or power exists about us in various forms: in heat, in the motion of bodies, in chemical action, and electricity. Energy can never be created, nor can it be destroyed; it can only be changed from one of its forms to another. When a certain amount of energy is furnished to a machine, we can never receive back from the machine, in another form, any more energy than was given it. When the motion of a body of water is made use of to drive a water wheel that furnishes power to run a dynamo, or when the chemical energy in coal is changed into heat under a steam boiler, an engine operated by the steam, and a dynamo operated by the engine, we have good examples of the changing of energy from one form to another.

In using the battery to furnish electrical energy, zinc and other chemicals are consumed; while in running the

dynamo, coal or other fuel is the material employed. In both cases energy in the chemical form is changed into energy in the electrical form; but the fact that many times as much electrical energy can be obtained from one dollar's worth of coal by the use of the dynamo, as by one dollar's worth of zinc used in the battery, makes the dynamo the practical method as regards expense, and renders the use of the battery out of the question. Besides, a battery requires a great deal of attention, occupies a great deal more space than does a dynamo of the same power, is very uncertain in operation, produces dangerous fumes, and is generally unsatisfactory.

THE DYNAMO.

THE principle which underlies the operation of the dynamo is as follows: — An electromotive force (p. 4) is produced in a conductor (p. 3), which is made to move through a region in which magnetic force is acting. Such a region is called a magnetic field, and an example of one is the space between the two poles or ends of a common "horse-shoe" magnet. The magnetic force in such a case may be mentally pictured by drawing a number of imaginary lines from pole to pole. It is along these lines that the magnetic force acts, and they are called lines of magnetic force. It is only when the conductor is so moved as to "cut" through these lines of force that an electromotive force is produced in it, no electromotive force being produced if the conductor is moved parallel to the lines.[1] Of course, if the electro-

[1] The amount of the electromotive force generated is greater as the strength of the magnetic field and the rapidity of motion of the conductor are greater.

motive force produced is allowed to act in a closed circuit (p. 3), a current will flow.

In a practical dynamo of the simplest form a large horseshoe magnet is used to furnish the magnetic field, the lines of force of which pass from pole to pole. Such magnets are called field magnets, and they are always electromagnets (p. 3). Between the poles of the field magnet, mounted on a suitable shaft and bearings, is the armature which carries the conductors that "cut" the lines of force, and in which the electromotive force is set up. It is to the pulley upon the shaft of the armature that the power is applied to rotate it. The armature is generally a cylinder built up of sheet iron with its shaft at right angles to a line joining the field magnet poles. It is built of iron in order to strengthen the magnetic field, as the magnetic force acts much more powerfully through iron than through air, or anything else. Upon the surface of this iron cylinder are placed the insulated copper wire conductors in which the electromotive force is to be generated. They envelop the armature in various ways; but there are two general methods, to be described later. In an ordinary dynamo the electromotive force which the various conductors generate are added together in various ways, but in the simple machine now being described the electromotive force which it produces is that obtained by adding together the electromotive force produced by one half the conductors. The electromotive force generated is really alternating, being in one direction in any conductor for one half a revolution and in the opposite direction for the other half; but while the current due to such alternating electromotive forces is very useful, it is not entirely suitable for power transmission and some kinds of lighting. For these purposes the current is required to be continuous; that is, to flow in the same direction at all times, as does a battery

current. In order to change the alternating current, which the dynamo naturally gives, into a continuous current, a commutator is used, which is simply an arrangement for automatically reversing the connection of each armature conductor to the circuit, just at the instant that the electromotive force due to it is reversing its direction. In this way a current of a constant direction is obtained. This commutator is built up of parallel copper bars, suitably connected to the armature conductors, insulated from one another and grouped into a cylinder which is carried on the shaft along with the armature. The stationary copper or carbon strips which bear upon the commutator at opposite points are the brushes which carry away the current to the external circuit.

DESCRIPTION OF PARTS.

THE field magnet of the dynamo is, as has already been stated, an electromagnet, and is accordingly surrounded with one or more coils of copper wire, generally furnished with current from the machine itself. The portions of the field magnet where the magnetic lines pass from it into the armature are called poles. The number of poles in most continuous current machines is two, but in large machines intended to run at a slow speed, four, six, eight, and ten, and more poles, are sometimes employed. These machines are called multipolars, and usually require as many field coils, or spools, as there are poles. The intention in the design of field magnets is to cause as many lines of force as possible to pass through the armature,

with as small expenditure of electrical energy in the field coils as possible, and to accomplish this without making the magnets too large, heavy, or expensive, or without winding on too much expensive copper wire to form the spools. The magnets of good machines are therefore of the best quality of wrought iron of liberal cross section, and of compact form, so as to offer as little resistance as possible to the passage of the magnetic lines, and hence require less electrical energy to be expended in the spools. For the same reason the clearance between the armature and the poles is made as small as possible. The field spools are preferably made to surround the limbs of the magnet near the armature, and are excited or furnished with current in three principal ways. (1) Shunt excitation (Fig. 8) is produced by passing the current from one brush through the field spools successively connected in series to the other brush. The spools thus receive the whole electromotive force of the machine, but their combined resistance is such that they only receive a very small fraction of the total current of the machine. This method of excitation is used on the great majority of continuous current incandescent light machines and some power generators. Such machines are called shunt

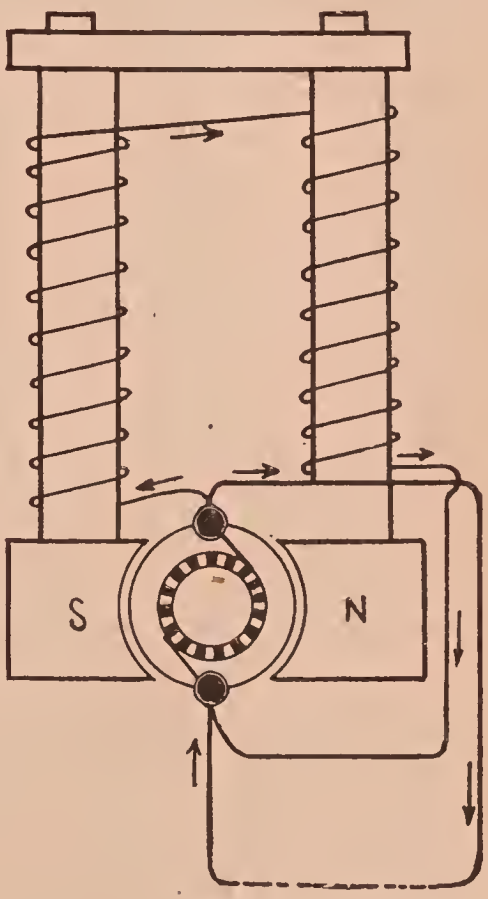


Fig. 8.

machines. (2) Series excitation (Fig. 9) is effected by connecting the field spools in series with the armature, thus allowing the whole current which the machine generates to pass through them. They are generally of so few turns of such coarse wire that their resistance is so

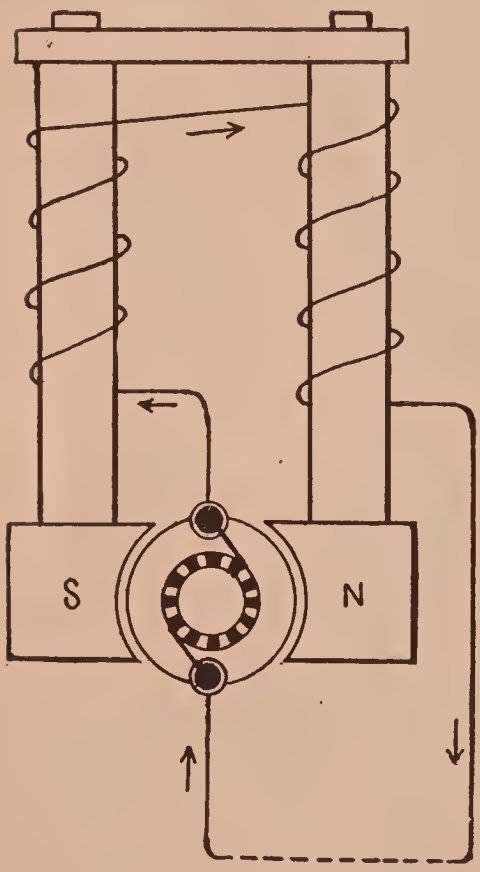


Fig. 9.

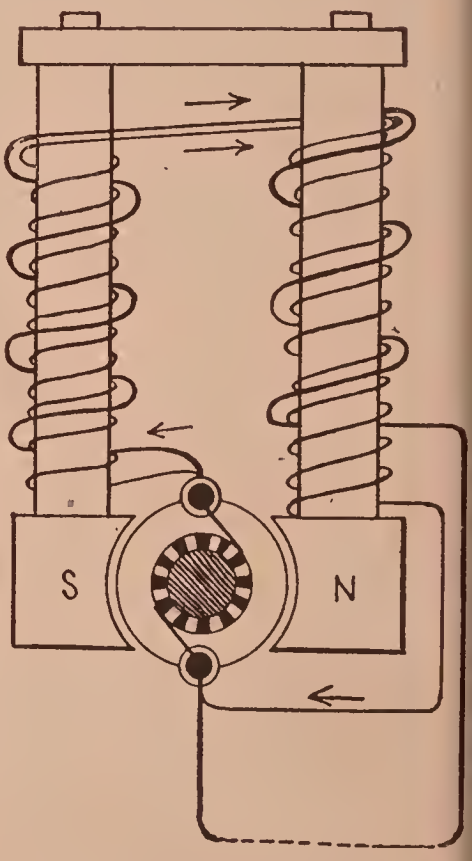


Fig. 10.

low as to reduce the voltage which the machine furnishes to the circuit but very little. Arc machines are almost always excited in this way, as well as street railway motors, etc. They are called series machines. (3) Compound excitation (Fig. 10) consists of a combination of shunt and

eries excitations — the spools being not only provided vith a fine wire winding of many turns through which a mall current circulates, but also with a coarse winding of few turns through which the whole current of the machine asses. Street railway generators and alternating current lynamos are generally compound excited.

The regulation of a machine to give the electromotive orce required is generally effected by regulating the current in the spools, thus changing the effect of the field nagnets. The e.m.f. produced increases as the current n the spools increases, owing to the increased strength f the magnet, and *vice versa*.

The armature core is generally built of a large number f thin circular discs of very soft sheet iron threaded on o the shaft and pressed together by lock nuts; a smooth vell-balanced cylinder is thus formed, capable of running lose to the field magnet poles with safety. The necessity f building up the cylinder of thin discs, instead of making t solid, will be explained when the "losses" in dynamos re spoken of. Instead of a solid cylindrical form, some ores are composed of ring-shaped stampings clamped ogether and held upon the shaft by suitable metallic "spiders." This is the ring, or Gramme armature, and f course necessitates a different method of applying the conductors from the cylindrical or drum construction. The necessity of having a core well balanced and firmly fixed to the shaft, considering the high speed at which it is to run and the large amount of power it is to absorb, is very clear. Frequently cores of both the cylindrical and ring form are toothed; that is, are built up of stampings having much the same appearance as gear wheels. When put together, the spaces between the teeth furnish slots for the windings, grooves on the surface of the core parallel to the shaft.

In winding continuous current armatures with the conductors in which the e.m.f. is to be set up, two general methods are followed, according as the core is of the cylindrical or ring form. In ordinary two-pole cylindrical armatures (Fig. 6) each turn of wire wound lengthwise of the core envelops nearly the whole of the iron, while in the ring armature (Fig. 7) the wire is threaded through and through the ring, each turn enveloping one half the total cross section of the iron. In both cases the winding in practice covers evenly the whole armature surface, and is divided into a great

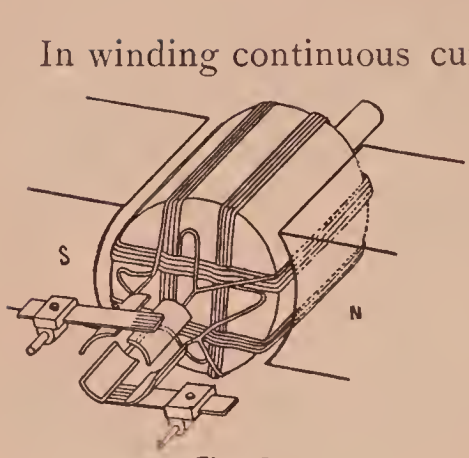


Fig. 6.

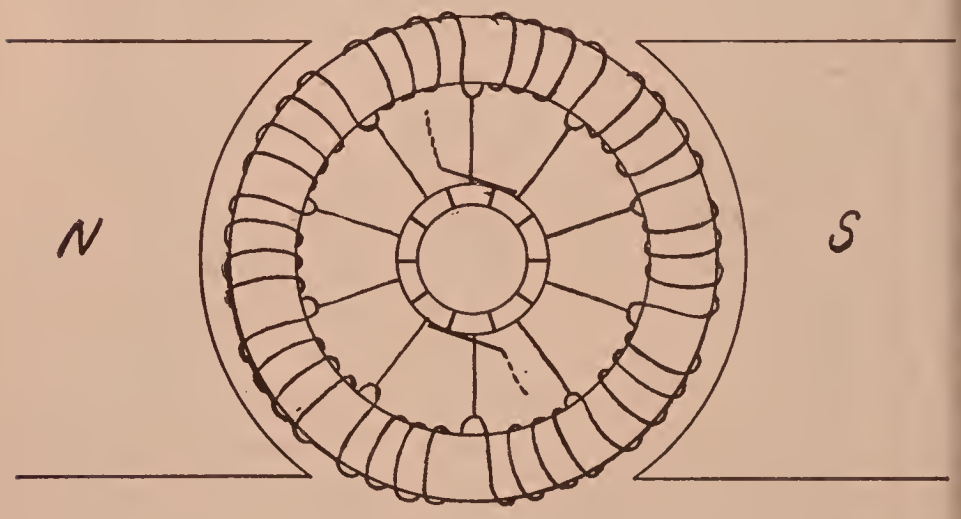


Fig. 7.

many separate coils, suitably connected to the commutator. Armatures for multipolar machines differ in the manner of making the commutator connections. Full descriptions of all kinds of armature windings and, indeed, concerning any feature of the dynamo, may be found in

. P. Thompson's "Dynamo Electric Machinery." The
ısulation of the armature conductors from one another
ıd from the core is perhaps the most vital point in
ynamo construction. If this is not carefully attended to,
ıe armature is very likely to be ruined by short-circuiting,
r the useless and dangerous flowing about of the cur-
ent in the armature coils instead of it following the
xternal circuit. The iron core should be very carefully
ɔvered with paper and cloth covered with shellac, and
ıe coils, wherever they overlie one another, should be
eparated by shellacked cloth or paper. Mica is good for
ıch insulation.

Cylinder and ring armatures with smooth cores, that
, not of the toothed variety, have to be provided with
ands of German silver wire wound tightly over the sur-
ıce, in the plane of rotation, and carefully insulated from
ıe winding, for the purpose of holding the armature con-
uctors in place. For large armatures running at high
peeds these bands have to be very carefully proportioned
ɔ withstand the severe pull upon the conductors by the
ıagnets and the strong tendency of the conductors to
y outward. An armature ought never to be allowed to
un at a speed much higher than that for which it is
ntended.

The commutator of the dynamo is a device, as already
tated, for the purpose of obtaining a continuous or direct
urrent from e.m.f.'s which, in any individual coil, are of
n alternating character — reversing direction every half
evolution. By means of it the connection of any coil to
he circuit through the brush is reversed just at the in-
tant when the direction of the e.m.f. in it is reversing.
n connecting the coils of an ordinary two-pole machine,
he last end of one coil is connected to the first end of the
ıext by attaching both wires to the same commutator bar,

the last end of this coil is connected to the first end of a third coil by attaching both to the next commutator bar, and so on around the whole armature, there being as many commutator bars as there are coils. This will be made clear upon reference to Figs. 6 and 7. In multipolar machines the method of connecting coils to the commutator is the same as in a two-pole machine, except that the coils occupying similar positions under alternate poles are connected together. Commutators should be of good length, of a perfectly smooth cylindrical surface, and the hard copper bars which compose them should be very carefully insulated from one another by mica, as well as from the shaft, upon which they should be firmly held. The commutator connections, or conductors which connect the armature coils to the commutator bars, should be carefully protected from being broken, and from accidentally becoming connected together by the failure of the insulation between them.

Upon the commutator bear the brushes, two sets being used in ordinary two-pole machines, and indeed, in some multipolars, which more often, however, have as many sets as there are poles. The two sets are made to bear upon the rotating commutator of a two-pole machine at points diametrically opposite, and are carried in brush holders upon a yoke, by means of which they may be moved together around the commutator, always remaining opposite. The position of the brushes is a matter of extreme importance, and will be spoken of later. The material of the brushes of the majority of machines nowadays is carbon, although most arc machines and alternating current dynamos still use copper leaf, copper gauze, or copper wire brushes. The conductors leading from the brush-holders to the circuit should be of especially flexible cable, so as not to be broken by the frequent movement of the brush-holder yoke.

Having thus briefly and incompletely stated the principles upon which the dynamo acts, and having defined and slightly described its most important parts, it is now necessary to touch upon a few points common to the operation of all dynamos. It has already been stated that the output of any continuous current dynamo, or its rate of furnishing electrical energy or power, is found by simply multiplying the current in amperes which it delivers by the e.m.f. in volts, which it furnishes to the external circuit as measured across its terminals. This result is the output in watts; the output in HP is obtained by dividing this by 746. The output in kilo-watts is a common method of rating dynamos, and is found by dividing the output in watts by 1000. Now, for every machine there is an output above which it is impossible to continuously operate it with safety. This is called the maximum safe output of the machine. This output is known to have been reached when any part of the wire of the machine becomes overheated, or when the machine begins to spark badly under the brushes, or when the belt, properly tightened, begins to slip on the pulley. If a machine is run at an output above the maximum safe output, it is said to be overloaded and is likely to be damaged or even destroyed. Overloading should be carefully avoided as much as possible, and the name plate of a machine should be consulted in this regard. The greatest allowable voltage and current are usually stamped upon it. In regard to the sparking under the brushes just referred to, and the causes which produce it, it may be well to say a few words here. The most common cause of sparking is the improper position of the brushes on the commutator. It will be seen by consulting Figs. 6 and 7 that the brushes are so made that, in passing from bar to bar, each one bridges two neighboring bars, leaving the coil

whose ends are connected to these bars short-circuited by it for an instant. Now, of course, at the exact instant when the e.m.f. in a coil is reversing, there is really no e.m.f. produced in it at all, and hence no current will flow through the brush as it short-circuits it. But, if the brush is in such position as to short-circuit the coil at any other than this exact instant, the e.m.f. which the coil is then producing will send through the end of the brush a very large current, which, when broken by the passing away of the brush, will cause a destructive spark. It is readily seen now why the connection of a coil to the circuit is reversed by the brush at the exact instant spoken of, rather than at any other. It is furthermore true that this position of the brushes gives the highest e.m.f. of any in which they can be placed. Sometimes sparking is produced by a rough commutator or loose brushes, the brushes actually jumping from the commutator surface and tending to break the main current. Sparking not only burns away the brushes and, far worse, roughens the expensive commutator, but wastes some electrical energy. If, with the greatest care, the brushes of a heavily loaded dynamo cannot be placed so as to prevent bad sparking, or if any part of the machine is more than 90° F. hotter than the air of the dynamo room, one may be pretty sure that it is overloaded, and the load upon it should be at once diminished. A dynamo is properly regarded as only a machine for changing energy in the mechanical form, such as a steam engine or water wheel furnishes, into energy in the electrical form. Owing to the presence of certain actions, no dynamo can convert all the power it receives into electrical energy, part of the power being inevitably changed into heat, which manifests itself throughout the whole machine. Of the mechanical energy delivered to the dynamo, that fraction which it converts into electrical en-

rgy for use in the external circuit is called its efficiency; nd the part of the energy which is changed into heat nd lost, as far as electrical uses are concerned, is called he "losses." As heat is produced in any conductor which is traversed by a current (see p. 4) part of this oss takes place in heating the wire with which the field nagnet spools and the armature are wound. There is eat produced, too, by the rapid reversal of the magnetism in the iron armature core as it revolves in the field; nd if it were not for the practice of building up the core f thin sheets, there would be much more loss in it, due o currents unintentionally set up in the core itself, just as hey are intentionally set up in the armature wires. The riction of the armature shaft in its bearings produces some eat, and there are various other minor actions which cause ome loss. The smaller these losses are, the larger will be he fraction of the power of the engine left as useful electrical energy; that is, the higher will be the efficiency, and in arge machines it may reach as high as 92%. A dynamo which runs hot, it is generally safe to say, is not of very igh efficiency. The selection of a dynamo best suited or a certain purpose must be based upon its first cost, ts efficiency, the amount of floor space it requires, its weight, and the amount of attention and repairs it is likely o call for. A small, light, cheap dynamo is sure to be of rather low efficiency, while a machine of high efficiency is generally much more large, heavy, and expensive. It may be stated generally that a dynamo which is to run almost continuously at nearly its maximum output should be of rather higher efficiency, and hence higher first cost, than a machine which is to be run only a small part of the time, mostly at a small output. The value of floor space should also be taken into account when considering this question. Many people, although they are aware that the dynamo is

a machine which absorbs a very large amount of mechanical energy in proportion to its size, do not see exactly how this power is expended, or why a loaded dynamo "turns hard." This point is made clear when we remember (p. 3) that a conductor, such as an armature wire carrying a current, has all the properties of a magnet, and that these "wire magnets" are moved in the vicinity of the field magnet only by overcoming the magnetic attraction and repulsion between the wires and the magnetic field. One may become familiar with these actions by experimenting with the attraction and repulsion of a couple of small horse-shoe magnets.

Dynamos are divided into two classes according to the manner in which they supply their energy to the external circuit. 1. A constant potential dynamo is one which is arranged to furnish the same electromotive force to the circuit, no matter what the size of the current flowing in it may be. (See Ohm's Law.) 2. A constant current dynamo is one which is arranged to maintain the same current in the external circuit, no matter how high an e.m.f. may be required to overcome its resistance sufficiently to do so. (See Ohm's Law.) These two classes of machines differ in their methods of excitation and regulation. Constant potential is secured by compound excitation or even very nearly by shunt excitation. Constant current is usually attained by the use of series excitation and some mechanical regulating device. Constant potential machines are employed in almost all incandescent lighting and transmission of power work, while constant current machines run nearly all the arc lamps.

CARE OF THE DYNAMO.

One of the most important points in the care of a dynamo, and, indeed, of all electrical machinery, is the

election of a suitable place for it. The only way to pre-ent deterioration of the insulation and the probable early estruction of a dynamo armature is to exclude all damp-ess, and all dust and shavings, especially of iron or other netals. There should be no overhead water or steam ipes or automatic sprinklers near the dynamos, lest they llow water to drip upon them; and oil-cloth covers hould be provided with which to cover the machines hen not in use. These should not be put on when the nachine is very hot. The flooring of the dynamo room hould be very dry, and the wood thoroughly "filled" ith oil to exclude moisture. The building must be very ubstantial to withstand the weight and vibration of the eavy machines. If the dynamos are placed in the base-ent, which makes the providing of firm foundations for hem an easy matter, a good flooring of oil-filled plank hould be put down over the cement or concrete. Deep rick piers are the only foundations good enough for eavy machines; upon these are placed the wooden slid-ng bases upon which the machines are mounted. It is ery important to insulate in some degree the machines om the piers, by using dry oil-treated wood for the bases. The placing of the dynamos so as to economize floor pace and yet not to so crowd them as to make the at-ndant's duties dangerous, ought to be carefully con-dered. The possible addition of new dynamos should e provided for. Indeed, in this work one has to be con-antly thinking of the future, and ought to aim to do as ttle work as possible which will soon require to be done ver. The great majority of dynamos in use are driven y belts from the engine pulleys or from pulleys upon a ain shaft, but many private dynamos are directly con-ected to the engine, the engine and dynamo being ounted upon the same base and having their shafts

connected by a suitable coupling. This arrangement requires less room than a belted dynamo of the same output, as the space taken up by the belt is saved, and where floor space is limited this advantage may more than make up for the somewhat greater cost of the direct driven arrangement. The belts used for driving dynamos should be of the very best quality, and of ample size to transmit the greatest power that the dynamos are capable of safely receiving without undue slipping. The steadiness and promptness of the regulation of the engine are of the greatest importance, especially in incandescent lighting, although it is very essential in transmission of power work and even in arc lighting. A very slight irregularity in the dynamo speed can be noticed in incandescent lights — even so slight a one as that produced by a stiff lap in the driving belt, and any fault in the government of the engine is very noticeable. An engine ought to be able to instantly change from full to no load — a change taking place very often in electrical work — without showing any signs of "racing." It is the lack of good regulation which has prevented water wheels from being used in a great many instances in which they might otherwise have been employed. The care of bearings is one of the most important points in dynamo tending, for the dynamo is a machine, the shutting down of which during working hours, means a great deal of annoyance and expense. It must be kept running at all hazards, and to do this hot bearings must be prevented. With the modern self-oiling bearings, in which a loose ring on the shaft continually carries oil from a reservoir over the bearing surface almost no attention is required, except occasionally to fill up the oil reservoirs, draw off the old oil, and keep grit and dust out of the bearings. Most modern dynamo bearings are self aligning and self adjusting, so that heat

ing is now seldom produced by non-alignment or by caps too tightly screwed down. Ordinary bearings with sight feed oil cups are familiar to everyone; they only require a little care and watching to give good results. If a bearing does become hot, it is probably due to lack of oil, grit in the bearing, caps set down too tight, or poor alignment of the shaft with the bearing.

Cold oil poured rapidly through the bearing will cool it gradually. Many engineers prefer to use heavy oil for this purpose.

Before going on to the electrical points which bear upon the subject of the care of dynamos, it will be well to add a few words concerning the matter of personal safety in handling electrical machinery. The danger, which is greatly exaggerated by most people, is of three kinds: the ordinary danger due to high speed belts and pulleys, electrical shocks, and electrical burns. Nothing need be said in regard to the former, except that sufficient space should be provided in the dynamo room so that the attendants may not be required to pass through dangerously crowded spaces between belts or moving machinery; that suitable guards should be provided for the belts, to catch them in case they accidentally come off the pulleys; and that all large high speed pulleys should be built with wooden rims to reduce the danger from bursting.

The constant possibility of heavy momentary overloads, to which electrical machinery is especially subject, makes these precautions very needful. In regard to electric shocks, it may be stated that even a momentary continuous current, received in the usual accidental manner, when of a voltage much above six or seven hundred, may be dangerous. Alternate current shocks are far more painful than those from continuous current, and probably a much lower voltage would be dangerous. Of course if a shock

were received through a part of the skin that happened to be damp and more tender than that of the ordinary person's hand, and if the shock were to continue for some time, a lower voltage than that named might be dangerous. All electric shocks are to be avoided, and the best way to do this is to observe the following rule. (1) Never touch with two parts of the body at the same time, any two parts of an electrical apparatus, except when it is certain that there is no electromotive force between the parts touched. (2) Never touch with any part of the body any portion of any electrical apparatus unless it is certain that the place upon which one is standing is dry, and more or less insulated from ground. A dry board can usually be found to stand upon. (3) Avoid touching any part of a circuit which is being broken. This is to avoid the high voltage produced by the ceasing of the current in electromagnets which may form part of the circuit. The first rule is of course a very obvious one. The second refers to the danger due to a grounded circuit, which is illustrated as follows: Suppose some point in a circuit to have become in some way connected to the ground; and the dynamo attendant to be also grounded by either standing upon a damp floor, the ground, or by touching some grounded metallic body. Then when he touches the circuit anywhere else than at the grounded point, he will receive a shock more or less severe according as he touches it at a point far from or near to the grounded portion. The current will divide at the point touched, most of it following the wire, but a little passing through the attendant's body, through the earth, and back to the wire at the grounded point. This is a very common and very dangerous way of receiving shocks. No circuit ought to be run when grounded — especially an arc circuit. Among extremely dangerous machines and circuits, employing

currents of from 1000 to 5000 volts, should be included those for alternating current incandescent lighting and arc apparatus. By following the rule of keeping one hand behind the back or in the pocket when dealing with high potential apparatus, by noticing where one is standing, and by using insulated screw-driver and pliers, shocks may generally be avoided. Electrical burns may ordinarily be avoided by never allowing any part of the body to be nearer than is absolutely necessary to the point where a circuit is broken. It is the arc which follows upon breaking the current that does the burning. Its heat and brilliancy seriously injure the eyes if they are too near it; and it is a good plan to face away when a circuit is being broken, as well as to wear heavy rubber gloves for the protection of the hands.

Accidents will occur from electrical apparatus, but they are (more than accidents of almost any other kind) due to personal carelessness.

By far the greater part of the care required by a direct current dynamo or motor has to be given to the commutator and brushes, in order to avoid sparking, heating of the commutator, and noise. The adoption of carbon in place of copper as the material of brushes has done a great deal, however, to reduce this. In the first place, the commutator must be in good condition: its surface must be perfectly cylindrical, and high or low bars must be remedied, as they will cause sparking. If there is any considerable irregularity in the commutator surface, the armature should be taken out of the machine, placed in a lathe, the commutator turned down to a true surface, and finished by the use of fine sandpaper, *not emery cloth*. If there are only slight irregularities in the commutator surface, coarse and then fine sandpaper held on a suitable block will remedy the trouble. All traces of

copper chips and dust should be removed from the commutator and its connections before replacing the armature in the machine. It is never a good plan to use a file upon a commutator; it is far better to use sandpaper of different grades, finishing with a fine paper. Oil should not be allowed upon the commutator in any quantity, as it is likely to damage the insulation between bars. The commutators of machines using copper brushes may, however, be lubricated by applying a very thin coating of vaseline, sufficient to stop the noise which the brushes make. If the brushes used are of carbon, a little oil may be applied to the commutator, upon the end of the finger, to lessen friction and stop the chattering noise. People tend to lubricate commutators too much; and it is well to be on one's guard against doing so, or even attempting it at all upon very high voltage machines. Good modern machines are furnished with brush-holders, which not only give excellent electrical connection to the brushes, but allow them to accommodate themselves to the surface of the commutator, and to "feed" as they wear out. The holders are all mounted on a yoke by which they may all be rotated about the commutator, still keeping their proper relative positions. Carbon brushes are made either of the radial variety, bearing upon the commutator in the direction of the radius, or of the tangential type, which bear at an angle of 90° or less with the radial. Copper brushes are almost always tangential. Radial carbon brushes are beginning to be very largely used. They enable the armature to run in either direction without any change being required, and are easily made self-feeding and self-adjusting so as to require almost no attention. Tangential brushes, bearing as they do upon the commutator, allow of only one direction of rotation of the armature, and care must be taken not to run an armature "against

he brushes." When a machine is shut down, it is always est to remove the brushes from the commutator. Copper rushes may be made of either copper gauze, bunched opper wires, or copper leaf. They cut the commutator orse than carbon brushes, spark far worse, give rise to ore dangerous conducting dust, require frequent trim- ing and setting, and are not so readily made to take care f themselves for long periods of time. On the other and, they will carry off from the commutator, without ndue heating, a much heavier current than will carbon rushes of the same bearing surface. The fitting of arbon brushes to the surface of the commutator is easily ccomplished as follows: Place the brushes in the holders n their proper positions; wrap the commutator with coarse andpaper placed face up; then rotate the armature or the andpaper wrapping by hand until the brushes bearing pon it have been worn down to a proper surface. An xcellent fit can very quickly be obtained in this way. opper brushes generally have to be filed in a vice until he proper bevel is obtained, to give a good bearing upon he commutator when they are properly placed in the olders. They should never be run in a ragged or frayed ondition. The pressure of brushes upon the commu- ator ought never to be heavy, and it should not be ttempted to make a badly fitted brush work properly by ncreasing its pressure, causing undue wear and heating. The brushes of two-pole machines should bear upon the ommutator at exactly opposite points. These points can enerally be found by counting the bars. In four-pole nachines the brushes ought to be a quarter apart, and o on with the higher poled machines. Something has lready been said concerning the proper position of the rushes upon the commutator to give the least spark; the nly way of ascertaining their position is by trial, — mov-

ing the yoke which carries all the brushes until the mos satisfactory position is reached. In most machines, how ever, the brushes require a slight shifting when the loac changes, to keep down the spark. With carbon brushes this change is very slight. As has been remarked unde the subject of "output," the heating of a dynamo is a con sideration which, with sparking, limits the work it car safely do. It is always well to keep a sharp lookout fo overheating by occasionally feeling the field spools, anc holding one's hand in the blast of hot air which come from the revolving armature. When a machine is danger ously overheating a smell of hot shellac may generally be noticed. If overheating takes place at a load less thar the one for which the machine is intended, one may be pretty sure something is wrong, very likely in the arma ture. If it is ever necessary to run a machine at an over load, one should be very watchful to detect the first signs of overheating in time to prevent the destruction of the insulation by carbonizing it, and the consequent ruin o the armature or field spools. It is certainly safe to say that as long as one can bear the hand continuously on the hottest portion of a dynamo, it is in no danger from over heating. About the worst accident which can happen tc a dynamo is a short circuit. This generally comes about through a crossing of the circuit-wires, or some such acci dent, which makes the resistance of the external circuit almost nothing, and allows an immense current to flow, which would burn out the armature in a few moments. Many machines are protected by devices which automati cally open the circuit when this happens, but when this is not the case, the best plan is to instantly stop the excita tion, if the dynamo is shunt or compound wound, by breaking the field circuit, or by breaking the main cir cuit if the machine is series excited. A short circuit is

instantly recognized by the flashing at the commutator, the squeaking, or throwing off of the belt which it produces. One should be very vigilant in avoiding short circuits. A dynamo should always be started and brought up to the proper speed before its field is excited, and before it is connected to the circuit; this is to test the lubrication, condition of the belt, and engine regulation. Care should be taken that there are no loose iron articles lying about too close to the dynamo, as they are likely to injure the armature, being drawn into it by the magnetic attraction. The circuit or circuits which the machine is to supply should first be tested (see later); and it should be ascertained that no one is at work upon the circuits, especially if the voltage used is a dangerous one. If the machine is of the constant potential type (see p. 48), the field circuit should then be completed, and the excitation gradually increased by slowly removing from the field circuit the rheostat, or resistance, which is always supplied with such machines. The rheostat is usually a fire-proof box containing coils of resistance wire, which are connected to a series of contact plates upon the front of the box, to the extreme one of which one side of the field circuit is connected. A pivoted arm connected to the other side of the field circuit is made to sweep over these contact plates, making connection with them successively when rotated, and thus including in the field circuit more or less of the resistance, thereby regulating the field current. (Ohm's Law.) When the proper voltage has been reached, as shown by the voltmeter (see p. 59), the machine may be connected to the circuit. More or less adjusting of the rheostat is usually necessary from time to time to keep the voltage at the proper amount; and it should, therefore, be located in a convenient place near the voltmeter. The ammeter (see p. 60) shows the cur-

rent, in amperes, which the machine is sending out, and should be watched with a view of preventing an overload. Constant current machines are usually started by simply closing the main circuit after the machines have been brought up to the proper speed. In shutting down a shunt or compound machine the rheostat should be gradually turned back, and the field circuit finally broken. It should then be disconnected from the circuit. Constant current machines are usually shut down by simply opening the main circuit, although short circuiting the fields is a more safe method.

When it is required to run more than one constant potential dynamo upon the same circuit, some care is necessary. The machines should preferably be of exactly the same size and type, and it should never be attempted with alternating current machines. In case one of the machines is running upon the circuit and it is required to add another, the machine added should be excited up to exactly the voltage of the circuit, and then connected with the other machine. It may then be loaded to the proper point by increasing its excitation a little. It is of the utmost importance that the direction of the e.m.f. of the new machine is the same as those already in circuit. The load should be properly divided between the different machines. This is done by the rheostats. Increasing the excitation of any machine increases its load, and decreasing its excitation decreases its load.

It may be well to make a few suggestions concerning testing. The only apparatus which is usually at hand for this purpose is the magneto bell — a very handy, although not a very exact instrument. It is simply a small hand dynamo, and a bell such as is used in every telephone outfit. When its two terminals are connected through a resistance which is not too high, and the handle turned, the bell rings.

A dynamo should be frequently tested to see that the armature and field wire is properly insulated from the iron frame of the machine. If by connecting one terminal of the magneto to any part of the iron frame and the other to the armature or field wire a "ring" can be produced, it shows that the insulation has broken down, and the defective part — armature or field, as the case may be — should either be shipped back to the factory for repairs, or repaired on the spot if possible. A few hours before being started, every circuit should be tested for "grounds" by attaching one terminal of the magneto to a gas or water pipe, or any other good conductor connected to the ground, and the other terminal successively to the two wires of the circuit. If a "ring" can be produced, it shows the circuit to be grounded. The trouble ought to be removed before the circuit is started. An arc circuit should always be tested a short time before starting up to see that it is complete — as it always should be. One should be able to ring through the entire circuit when the two terminals of the magneto are connected to the two circuit wires. When a number of circuits go out from the same dynamo room and run closely together for some distance, it is well to test to see that there is no connection between separate circuits, such as might be caused by a "cross." This may be done by connecting one terminal of the magneto to both sides of one of the circuits, and the other magneto terminal to both sides of the other circuit. One should not be able to "ring" if the circuits are properly insulated from one another. This should be tried until each circuit is found to be insulated from every other one. The voltmeter and ammeter have already been alluded to as instruments for measuring the e.m.f. and the current.

The voltmeter is a very high resistance instrument, and

its terminals are connected to the points of a circuit between which it is desired to know the e.m.f. acting. In dynamo rooms it is generally arranged with its terminals permanently connected to the two main conductors which feed the external circuit. The ammeter is a very low resistance instrument, and is connected so that the whole current passes through it. In dynamo rooms it is "cut in" to one of the main conductors leading from the dynamo. Care should be taken never accidentally to allow it to be connected to points having an e.m.f. between them.

The electrical defects which are likely to arise in dynamos are of several kinds. In the first place the insulation of the armature conductors may prove defective either by having been injured mechanically or having been charred by overheating. If wires of different coils become connected, owing to this cause, or if there are connections established between the winding and the iron core at more than one point, heavy useless currents will flow through these internal short circuits, which will heat the armature so excessively and cause so much sparking as to render it unfit for use, If the armature happens to be of the ring form, with the coils not overlapping one another, it is generally possible to locate the trouble and remedy it by re-insulating the injured parts. But if it is a cylinder armature, in which the coils overlap each other, it is usually necessary to send it back to the factory to be rewound, unless, indeed, the defect happens to be upon the surface, where it can be gotten at.

Sometimes one may locate the defects in an armature by running it with no load, but with excited fields for a short time, and noticing which coils become most heated. These coils give a clew to where the trouble lies. A contact between two or more commutator connections is

a defect of almost the same kind. If it is discovered before the heating which is produced has spoiled the insulation of the short-circuited coils, the trouble can generally be remedied by re-insulating or by cleaning out the copper dust which may have formed the connection. This trouble is best located by the heating as just described. When the circuit through an armature coil is opened by the fusing or breaking of the wire, or by a commutator connection becoming broken or detached from the bar, serious sparking is produced between the two commutator bars to which the broken coil is connected. This coil may be located by running the machine with a load until the sparking has blackened the particular bars belonging to the damaged coil. If the break is in the commutator connection, or if in one of the coils of a ring armature, it would not be very difficult to make the needed repairs. It may be said in regard to armature troubles that it is very hard and unsatisfactory work to attempt to remedy any but the most trivial ones. One usually has not the facilities for conveniently and safely handling anything so heavy as a large armature. Besides, it is necessary to take off the band wires, if any coil is to be removed, and it is very difficult to replace them properly without the special machinery used at the factory. It is often better not to attempt any armature repairs except, perhaps, such slight ones as replacing a broken commutator connection or re-insulating some spot in the winding which is easily reached. It is far better to have a spare interchangeable armature for each kind of machine, to be used while the defective one is away at the factory being repaired. Every one should be able to find out, however, what the trouble in an armature is.

Repairing defective field spools is not so difficult, as the method of winding is simple. A field spool may have

its winding accidentally connected to the frame of the machine, perhaps grounding the circuit. If more than one such connection is formed, it will cause part of the field wire to be left out of circuit, causing sparking, and, in a shunt machine, heating of the spools. Or the field wire may become broken, making it impossible to excite the field. Enough has been said of the use of the magneto to enable one to recognize these troubles.

Unless the point where the trouble lies is very near the outside of the winding, it is well to arrange the field spool in a lathe to hasten the process of unwinding and rewinding. The defect can usually be found and remedied without much trouble, the insulation made secure, and the same number of turns of the same sized wire replaced as have been removed. While considering the fields, we are naturally led to mention the matter of non-excitation, or the failure of a machine to supply current for its own fields. This failure in constant potential machines may be caused by the field circuit being accidentally broken, either in the spools, the rheostat, or the connecting wires. It is well to go over all the connections carefully, tightening them securely if they need it. A shunt excited machine, if its armature is "dead short-circuited," will not excite its fields. This should be looked to carefully. Sometimes the brush-holders may be found accidentally connected together by both touching a part of the frame, or some other similar accident may have occurred. Constant current machines, which are series wound, may usually be started, if they give trouble, by short-circuiting the dynamo terminals with a piece of heavy copper wire for a small part of a second and then removing it.

The entire circuit, including the machine itself, should first be ascertained to be complete. For a full discussion of dynamo troubles, see "Practical Management of Dynamos and Motors," by Crocker & Wheeler,

HEAVY CURRENT APPLICATIONS.

INCANDESCENT ELECTRIC LIGHTING.

THE production of light by raising a conductor of high resistance to a white heat with an electric current is the principle of the incandescent lamp. Every one is familiar

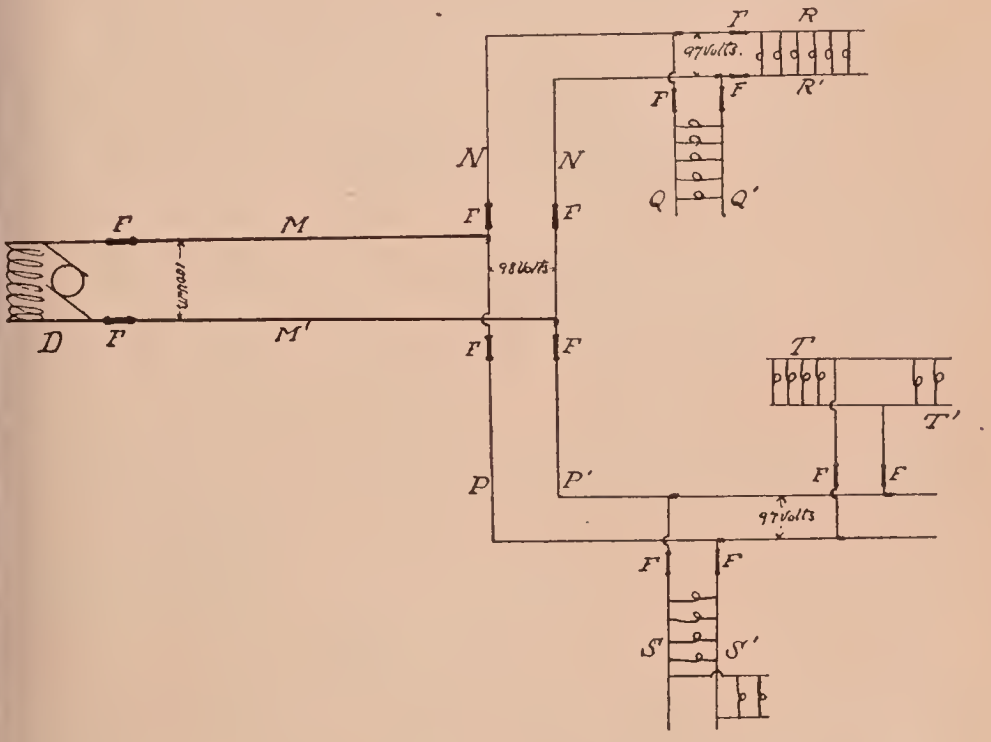


Fig. 11.

with the modern lamp, which makes use of a very fine carbon filament, or wire, heated in a glass bulb from which the air has been exhausted as completely as possible. Incandescent lamps are almost always supplied with current from constant potential machines (p. 48). The lamps are connected "in parallel" across the constant potential conductors coming from the dynamo. The filament of each lamp being subjected to the same voltage, and the lamps being all alike, each one will receive the same amount of

electrical energy and therefore burn with the same brilliancy, and be independent of all the others. In Fig. 11, D represents a constant potential dynamo, from which extend the constant potential *mains*, MM^1, which branch into the *sub-mains*, NN^1 and PP^1; these in turn are divided into the constant potential branches, QQ^1,

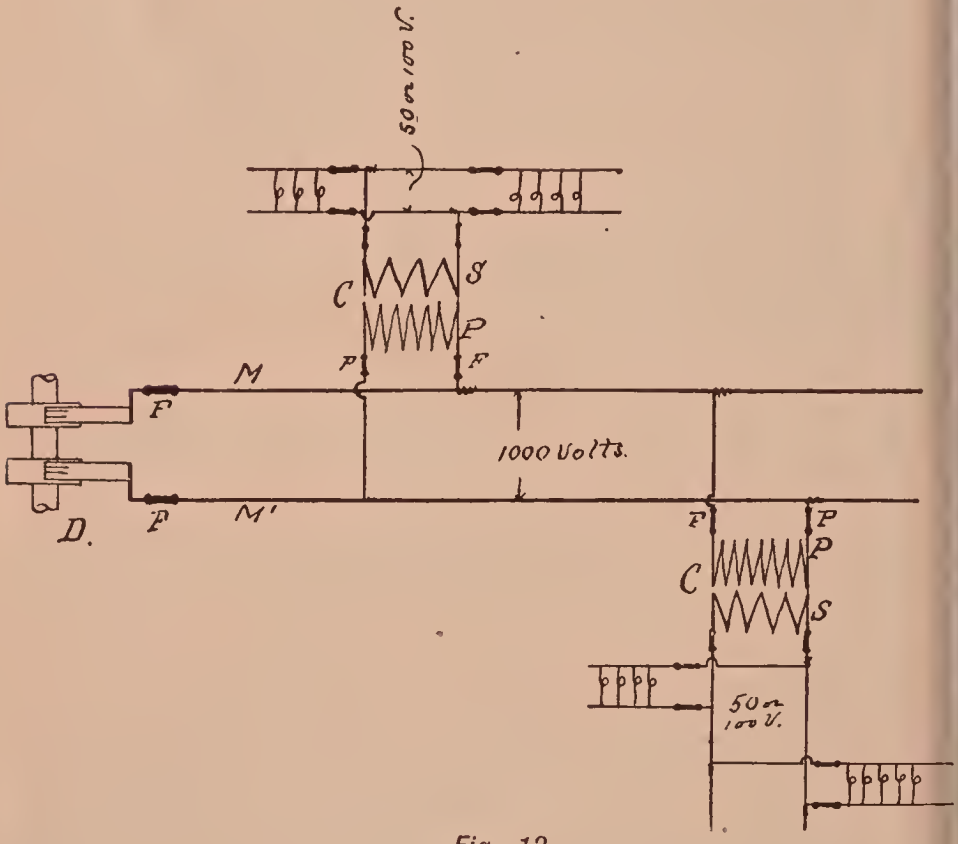


Fig. 12.

RR^1, SS^1, and TT^1, which supply the lamps. This is an example of *direct* incandescent lighting in which there is a direct electrical connection from the dynamo to the lamps. In the *transformer* or *converter* system, however, the arrangement is as in Fig. 12. D is a multipolar constant potential dynamo without a commutator, thus giving an alternating e.m.f., changing its direction perhaps two hundred times a second. Such a machine usually gives

a constant potential of about 1000 volts. MM^1 are constant potential, alternating current, 1000 volt mains, leading from the dynamo. Wherever lights are required, there is placed a transformer or converter, *C*, consisting of an iron core wound with two separate insulated coils of wire — one the *primary*, *P*, of many turns of rather fine wire, having its terminals connected directly across the 1000 volt mains, while the other, the *secondary*, of a few turns of coarser wire, has its terminals connected directly to the main house wire. In the secondary, and alternating e.m.f. of 50 or 100 volts, suitable for running lamps, is produced by *induction*, just as the shocking current in an ordinary medical coil is generated. As there is no electrical connection between the dangerous 1000 volt mains and the house wires, there is no chance for accidents to persons having to do with the lamps. The advantage of using converters is that the high voltage current from the machine (1000 volts) may be transmitted for a much longer distance upon a certain sized wire with a certain amount of loss than could a low voltage current of say 100 volts, representing the same amount of power, and used to supply lamps direct.

Less money has therefore to be expended for copper wire in the transformer system.

Although it has been stated that incandescent lamps are arranged upon constant potential circuits, yet it is not really possible to keep the voltage between the two wires exactly the same everywhere in the whole system. Every wire, however large, offers some resistance, and therefore some of the e.m.f. is used up in overcoming it. The number of volts used up in any wire is found by multiplying its resistance in ohms by the current flowing in amperes (see Ohm's Law). This loss in volts is called the *drop*, and the *per cent drop* is the drop in volts divided

by the voltage of the circuit. It is customary to allow a certain per cent drop, which must not be exceeded at any lamp in the system. The wires are then so proportioned as to give the proper resistance to secure the above result. Of course the drop is greatest at the time when all the lamps are burning, and the full current required by all the lamps should be used in figuring it. The drop should never be large enough to make a noticeable difference in brilliancy between lamps at times of heavy and of light loads. In buildings it is common to allow from one to five per cent drop in voltage as the maximum. Referring to Fig. 11, part of the drop, perhaps two per cent, would be allowed to take place in the mains, another per cent in the sub-mains, and very little in the branches.

The total drop to the lamps would then be a little over three per cent when all were burning. In order to be able to ascertain the size of wire required to run a certain number of lights taking a certain current and located at a certain distance, with a certain drop, it is convenient to use the following formula: —

Area cross section of conductor required in circular mils $= \frac{21.4\,L\,C\,N}{D}$, where L is the length in feet of the required wire for one side of the circuit, C is the current in amperes required by each lamp, N is the number of lamps to be operated, and D is the drop in volts allowed when all are burning. The current which any lamp requires may be found approximately by multiplying its candle power by 3.5 and dividing the product by the voltage employed. The result of the above formula is obtained in circular mils of cross section, and it is only necessary to consult the wire table and find the size of wire most nearly corresponding to this cross section. For example: Suppose we wish to run ten 32 candle-power lamps at the end of a

branch, one side of which requires 100 feet of wire; suppose the voltage to be 100, and the drop allowed to be two per cent, or two volts: —

Current required by each lamp $= \frac{32 \times 3.5}{100} = 1.12$ amperes.

Then $\frac{21.4 \times 100 \times 1.12 \times 10}{2} = 11984$ circular mils.

No. 10 (B. and S. gauge) wire is seen by the table to have a cross section 10,382 circular mils, and is the size nearest to that required.

Many important points relative to incandescent lighting installations, including the careful insulation of the whole circuit, the best and safest methods of constructing it, the use only of fire-proof fittings, and indeed all the precautions necessary to secure the best results, are treated of among the rules of the Fire Insurance Underwriters relative to electric wires, to which the reader is confidently referred. No heavy current installation should ever be made that does not conform in every particular to these excellent instructions.

In order to avoid danger from fire in incandescent lighting, as well as to avoid danger to the dynamo or transformer by overloading, fusible cut-outs (*F*, Fig. 11) are used to automatically open the circuit and interrupt the current when it becomes unduly large in any wire. If, for instance, the circuit wires, having the full voltage between them, accidentally become connected together, forming a short circuit, an immense current would flow in them, and in the absence of the fusible cut-out, heating or even melting them, and perhaps setting a serious fire, and at the same time injuring the dynamo or transformer. When each wire, however, has included in it a *fuse*, placed in a fire-proof *cut-out*, the fuse melts upon an extraordinary

increase of current and opens the circuit before the wires, either of the circuit or the dynamo, become dangerously heated. These fuses are strips or wires made of an alloy having rather a high resistance and a low melting point. They are made of sizes suitable to carry various currents, and melt if the rated current is much exceeded. There should be fuses in each side of the mains as they leave the dynamo, in the beginning of each side of each sub-main, and in each wire of each branch. In case lamps are suspended from the ceiling, it is generally easy to supply each individual lamp with fuses. The fuse in each wire should be such as just to carry the current required. This current is easily found by counting the number of lamps fed by the wire in question, and multiplying by the current required by each. It is best never to arrange more than six or eight lights to be protected by a single cut-out; and care should be taken that fuses when "blown" are replaced by ones of suitable capacity, not by heavy copper wire, as the writer has more than once seen done.

Incandescent lamps are commonly made of the following candle powers: 10, 16, 20, 32, 50, 75, 100, and 150; and voltages from 20 to 125 volts. The voltage of a lamp means the number of volts which has to be applied to the filament to cause it to give its rated candle power. Lamps require from three to four watts to be expended for each candle power of light produced. After a lamp has been burning some time the inside of the bulb begins to blacken, due to a deposit of carbon particles from the filament, the filament gradually wears away, and finally breaks. The lamp is then of no use and must be replaced by a new one. The total length of time a lamp burns before breaking is called its *life;* and 16 C. P. lamps, consuming 3.1 watts per candle, or a total of 50 watts each, ought to have, on the average, a life of 600 hours; while lamps

equiring four watts per candle may be expected to last at east 1000 or 1200 hours. This amounts to saying that he less power a lamp takes to give its rated C. P. the ooner it will have to be replaced, and *vice versa*. Thus here are two expenses connected with incandescent light-ng which depend on one another — the cost of the power nd the cost of lamps. To secure the best economy he sum of these two expenses should be made as small s possible. It is found that this result is attained where ower is expensive by using an economical lamp, giving ay one C. P. for 3.1 watts, but where power is cheap a amp giving one C. P. for each 4 watts is best. Instead f changing lamps to vary the economy in power, the oltage supplied to the lamps may be slightly increased r decreased above or below the voltage for which they ere intended, making in the first case a more economical ut shorter lived lamp, and in the latter one of longer life ut one less economical of power. Where power is very xpensive and 4-watt lamps have been installed, it is some-mes good economy to run them a little above the proper oltage, but never so much above as to cause them to give bluish light. If the cost of power is small or next to othing, it is well to keep down the lamp breakage by unning the lamps a little below voltage, but not so much s to burn yellow.

It is best to mark each new lamp when put into service ith the date; in this way the life of a lamp may be ap-roximately ascertained. It is easy of course to tell how uch power a lamp uses by means of voltmeter and am-eter of suitable size. The wearing away of the filament nd the blackening of the bulb are gradual processes; and s they progress the lamp gives less and less light, but, nfortunately, does not take proportionately less power. t is poor economy, especially where power is high, to run

old lamps after they have begun to burn at a dull yellow or orange. They had better be thrown away. The best lighting effect is obtained from incandescent lamps by arranging them tip downward or in a slightly oblique position under metallic or china reflectors. One of the great advantages of the incandescent lamp is that it may be placed to throw its light where most needed. In lighting rooms of ordinary height, one 16 C. P. lamp for each 80 sq. ft. of floor space will give good illumination and it is better, except where appearance is of great importance, to distribute the lamps about uniformly, hanging them on pendants from the ceiling, rather than arranging them in clusters upon one or two fixtures. Nothing will be said of the switches introduced into circuits to make and break the current and thus control the lights; of the sockets into which the lamps screw automatically making connection with the circuit; or of the various kinds of shades, globes, and other fittings which are used in incandescent lighting. They are easily understood and applied.

THE ARC LIGHTING SYSTEM.

When a current of electricity is made to pass from one carbon point to another, through a small air gap, a very brilliant light is given out by the intensely heated ends of the carbons, and by the arc, as the highly heated carbon vapor between them is called. The heat produced is of course due to the high resistance which the space between the carbon points offers to the current. (See p. 4.)

A pair of such carbon points, suitably supported, end to end, with mechanism for automatically starting the arc by separating the carbons and maintaining them at a

uniform distance apart, is an arc lamp. The carbons of arc lamps gradually burn away when in use, the upper carbon being arranged to burn about twice as fast as the lower one, and to feed downward automatically to keep the length of the arc uniform, the lower carbon remaining stationary. This feeding of the carbon, as well as the starting of the arc, is accomplished by allowing the smooth brass rod which carries the upper carbon to pass through a *friction-clutch*. This clutch is generally mounted upon a lever, the raising or lowering of which separates the carbons or allows them to approach one another. An electromagnet suitably wound, acting against a spring, controls the position of this lever, and automatically starts and maintains the arc at its proper length. Sometimes the upper carbon is carried upon a rack, the position of which is controlled by the electromagnet. Unfortunately there is such variety in the construction of arc lamps of different makers that nothing more than the foregoing general statement will be given. Arc lamps are usually arranged to burn in series; that is, the same current passes through each of them in succession; the wire coming from one terminal of the dynamo is connected, say, to the upper carbon of the first lamp, the lower carbon of this lamp is connected to the upper carbon of the second lamp, and so on. The wire from the lower carbon of the last lamp in circuit goes back to the other terminal of the dynamo. Ordinary arc lamps, which are rated at 2000 C. P., require a current of ten amperes and about 45 volts each, one lamp thus consuming about 0.6 of an electrical H. P. The dynamos used in arc lighting are usually series excited and of the constant current type (see p. 48).

The voltage produced increases as more lamps are included in the circuit, and decreases as lamps are cut out,

thus keeping the current of a uniform strength. This regulation is usually automatically accomplished by shifting the brushes so as to vary the e.m.f. given to the circuit, but it is sometimes done by automatically varying the field excitation. To give good service, an arc lamp should be kept perfectly clean, especially lamps that use a rod to carry the upper carbon. This rod should be thoroughly rubbed with a handful of clean waste each day when the carbons are replaced, or, in other words, when the lamp is trimmed. Only the best carbons should be used in order to obtain a steady white light, and care should be taken in trimming the lamps to get the carbons in good alignment so that they will not slip by and extinguish the light. An upper carbon ought to burn from seven to eight hours. If a lamp hisses continuously when burning, it shows that the arc is too short, and if a lamp burns blue, and flames, the arc is evidently too long. In most lamps the length of the arc may be regulated by adjusting the spring which acts upon the clutch mechanism in opposition to the electromagnet. A loose clutch may be the cause of an unduly short arc, while a dirty carbon rod may account for an arc that is too long or very irregular. Arc lamps should always be hung out of ordinary reach, as the voltage is usually dangerous, being 2500 in a circuit capable of running 50 lamps. There is always a danger that the circuit may be grounded, and it is best that the public should not be able to handle it. The distribution of light, moreover, from lamps placed rather high is very favorable. Each lamp should have a switch arranged to completely disconnect it from the circuit, so that the attendant may handle it safely while the rest of the lamps are running. Care should especially be taken that an arc circuit is never opened accidentally, as all the lamps are extinguished if the circuit is broken at

any point. In connecting new lamps to the circuit, or starting up a new circuit, it is important to see that the lamps are burning "right side up." The current should be in such a direction that the upper carbon is most rapidly consumed, showing an intensely bright hollow on the end, called a crater. The lower carbon should be pointed. If lamps are burned wrong side up, the lower carbon holders are likely to be burned and the distribution of light very poor.

A smoked or dark-colored glass should be kept on hand through which to watch the arc without injury to the eyes.

The Underwriters' Rules give instruction for installing arc apparatus, and these rules should be carefully followed. The size of wire generally used for arc circuits is No. 6 B. & S. gauge.

TRANSMISSION OF POWER.

If a dynamo be suitably furnished with electrical energy, its armature will revolve and transform a greater or less part of the energy thus supplied it into useful mechanical power, suitable for running any sort of machinery. A reversed dynamo so running is an electric motor, and furnishes a ready means of transmitting mechanical power from place to place along an electric circuit.

Either a shunt or series dynamo may be used as a motor, and it may be operated upon either a constant current or a constant potential circuit. The shunt motor operated upon a circuit of constant potential (usually 500 volts) is so universally used for stationary power purposes that it alone will be treated of. Street car motors are usually series wound, and operated upon 500 volt circuits.

The revolution of a motor armature by energy supplied it is due to the same forces which act against the revolution of a dynamo armature — the attraction and repulsion of the armature conductors by the field; and when a motor is in operation there is also the same action as in a dynamo, the production of an e.m.f. by its armature conductors cutting the field. This e.m.f. is nearly equal to and in the opposite direction from the e.m.f. of the circuit upon which the machine is running, and therefore tends to reduce the current that passes through the motor armature, which is usually of so low resistance that, were this "back e.m.f." not present, a sufficiently large current would flow in the armature to injure it immediately.

It is thus important for the safety of a motor never to allow its armature to be connected to the circuit (unless properly protected) when this back e.m.f. is for any reason absent, which is, of course, the case when the field is not excited, and also the case until the armature has begun to revolve, for in neither instance are the armature conductors cutting lines of force. In starting a shunt motor, the fields may be excited before the armature is connected to it, so that the moment the armature begins to revolve it will begin to generate a back e.m.f., while to compensate for the lack of the back e.m.f. before the armature starts, a rheostat of suitable resistance is connected in series with the armature, and gradually entirely "cut out" as the machine speeds up; this cuts down the current which would otherwise flow, so that the armature is in no danger. It is of great importance, especially with a shunt motor, to be sure that the armature circuit is open and that the resistance of the rheostat is all in before the machine is in anyway connected to the circuit. It is well, too, in doubtful cases, after the field circuit is closed, to test the field with a

piece of iron to show that it is excited. It is safe then to close the armature circuit through all the rheostat resistance. All the connections of the field circuit should be very carefully made, to avoid the possible breaking of the field current while the motor is running. In case, as sometimes happens, the supply of current from the circuit ceases while the motor is in use, the machine should immediately be disconnected from the circuit and the rheostat turned back to the starting position with all its resistance in, otherwise, should the circuit start up again, it would find the motor stopped and without a back e.m.f., and damage might result. Automatic devices are made which protect motors from damage due to this cause or careless starting.

Motors should be protected by the best form of fusible cut-outs, with fuses properly proportioned to carry the full load current of the machine. A motor should never be overloaded by requiring it to do unduly heavy work, causing the current which it takes from the circuit to be so much increased as to produce dangerous heating or sparking. An ammeter should be provided in circuit with the machine, so that the full load current, as stamped upon the machine by the maker, may never be exceeded without the fact being evident. A good shunt motor ought to run at nearly constant speed (within 5%) at all loads less than its maximum; and a machine running at not too high a speed is preferable, as it may be belted direct to the work, thus dispensing with the use of counter-shafting in many cases, and requiring a little less attention. It is generally better also to purchase a motor which is somewhat larger than there is immediate use for, in order to allow for an increase in the load.

Reasonably constant voltage of the supply circuit should be demanded from company furnishing the power, as with-

out constant voltage the shunt motor loses one of its great advantages — its nearly uniform speed.

Since a motor is nothing more nor less than a reversed dynamo, it requires the same care in securing a good place for it, in looking after the commutator, brushes, and bearings, and in preventing damage to it by overload or otherwise.[1] It may be stated that in almost all respects a good dynamo makes a good motor, and *vice versa*. In wiring for and installing a motor, the Underwriters' Rules upon the subject should be conscientiously followed, and, as in the case of incandescent lamps, the proper size of wire for the purpose is easily found by the use of the following formula: —

$$\text{Circular mils of cross section of required wire} = \frac{15964\ N\ L}{E\ V\ Y},$$

where N is the number of H. P. for which the motor is intended, L the length of one side of the required circuit, E the voltage of the circuit, V the drop in volts, and Y the efficiency of the motor, or the fraction of the electrical energy supplied it which is changed into useful mechanical power. For example: Suppose the motor to be a 10 H. P. machine of .9 efficiency, to be run from a 220-volt circuit, with a drop of 5 volts, and that 100 feet of wire are required for each side of the circuit leading to it. Then

$$\text{Circular mils} = \frac{15964 \times 10 \times 100}{.9 \times 5 \times 220} = 16125.$$

No. 8 B. & S. gauge wire is seen by the wire table to have a cross section of 16510 circular mils, and is therefore the size nearest to the one required.

As to the efficiency of electric motors, it is quite safe to expect 85% efficiency from fully loaded motors larger than

[1] Motors are too often left to take care of themselves under conditions very unfavorable to their successful operation.

one or two H. P., and even 90% is not uncommon in large machines doing their rated H. P. The remarks made concerning dynamo losses, and concerning the relations between first cost, weight, size, and efficiency of dynamos, are also true of motors. The instructions concerning the detection and remedy of the various troubles to which dynamos are subject also apply here.

THE STORAGE BATTERY.

STORAGE BATTERIES are beginning to be largely employed in connection with electric plants, and are likely in the near future to prove of immense practical importance, as they furnish a means of storing electrical energy, acting to all intents and purposes as electrical reservoirs, which, when filled, may be drawn upon as required. A storage battery consists of a number of storage cells connected as are ordinary battery cells — generally in series. Each cell usually consists of a suitable jar filled with dilute sulphuric acid, in which are placed two sets of prepared lead plates, one set being made of spongy lead, and the other of lead oxide supported upon metallic lead. When a current of electricity is passed in the proper direction through such a battery, the plates and acid are altered chemically in several ways; but the principal change is the production of hydrogen and oxygen gas, the former being absorbed by the spongy lead plate, and the latter entering into chemical combination with the lead oxide of the other plate. This chemical action represents the expenditure of a certain amount of electrical energy, and may be changed back into the electrical form at will, to be used for any desired purpose.

Passing a current from a dynamo or other source through the battery is called "charging," and when the chemical process which it produces is complete the battery is said to be "charged." The dynamo may then be disconnected, the battery connected to an electric circuit, and it will give out during its discharge an amount of electrical energy equal to 70 or 80% of that which was furnished it by the dynamo. It is evident that storage batteries are of great value in electric lighting plants which are intended to furnish a continuous service, but where it is not economical to operate the machinery all the time. In such a plant the dynamo is operated during only a portion of the day, supplying the lights and charging the battery simultaneously. The dynamo may then be shut down and the battery left to take care of the load during the rest of the day, thus reducing the amount of attendance required by the plant. Other valuable applications of the storage battery are readily suggested. Each storage cell furnishes an electromotive force of about two volts, and has a very low internal resistance, on which account a cell should never be short-circuited, as the current delivered would be enormous and would seriously injure the plates.

In charging a storage battery certain precautions must be observed. Before connecting the dynamo to the battery it should be running at its normal speed, and should have its fields excited so that it gives a voltage just equal to that of the battery. This may readily be determined by means of a voltmeter. It is of the greatest importance to be certain, before the dynamo and battery are connected, that the electromotive forces which they produce are in opposite directions, otherwise a short-circuit of the worst description will be the result. It is easy to determine the direction of the electromotive force acting in any

circuit by means of a small pocket-compass and the application of the following rule: Arrange a portion of one of the wires of the circuit horizontally in a SOUTH and NORTH direction; place it directly OVER the compass needle, and if the electromotive force is acting from south to north, the north pole of the compass will turn to the WEST.[1]

If the foregoing directions are carefully observed, the dynamo and battery may safely be thrown together, and the voltage of the dynamo raised sufficiently to cause it to deliver the proper strength of current to the battery. If the dynamo is excited to a voltage less than that of the battery, the battery will discharge through it, running it as a motor. This state of things may be detected by noting which is the loose and which the tight side of the dynamo belt, thereby determining whether the dynamo is doing work or is having work done upon it. It is necessary that the speed of the dynamo be very constant, as otherwise it may decrease sufficiently to allow the voltage to fall below that of the battery, when the state of things just described would be attained. It is of great advantage to have an automatic switch arranged to open the circuit, in case the current reverses from its proper direction. Even an indicator arranged to ring a bell if this happens is a useful device.

The strength of the current furnished the battery during charging is a matter of some importance. It should never be so great as to cause the cells to give off much gas, except during the latter part of the process. A better efficiency is obtained from the battery if the charging current is so small as to not cause the cells to gas at all, but a much longer time is required to complete the process. Charging may be considered to be complete when the cells gas violently even on a reduced current.

[1] The initial letters of the principal words of this rule form the word SNOW.

The current which flows during discharge ought generally to be less than the charging current, and the discharge of a battery should not be carried so far as to cause its voltage to rapidly diminish. A storage battery in good condition, with good insulation, ought to retain its charge for months if not used. A slight loss, due to leakage and other causes, is, however, inevitable. A battery ought not to be left for any great length of time in a discharged condition. The acid used in the cells ought to be kept at the strength prescribed by the makers. The strength is indicated by the specific gravity, which may be measured by a hydrometer.

The voltage of each individual cell should frequently be tested by means of a suitable voltmeter, and any cell which falls much below the average should be carefully examined, in order to locate the trouble. A short-circuit among the plates is very likely to have happened, caused by the falling from its lead supports of some of the material in such a way as to bridge plates of opposite polarity. Possibly the cell may not have had so much charging as the others for some reason. It is best to have several extra cells on hand to take the places of any which may have to be removed.

The storage cells and the shelves upon which they rest should be kept perfectly dry and clean; and it is important that the battery be placed in a room where good ventilation is provided, as corrosive vapor and explosive gases are evolved during charge, which ought immediately to be disposed of. The contacts between the cells ought to be frequently inspected, with the view of keeping them firm and bright. The Insurance Underwriters' Rules in regard to storage batteries and circuits leading from them should be strictly followed.

PART III.

RULES AND REQUIREMENTS.

AS RECOMMENDED BY THE UNDERWRITERS' INTERNATIONAL ELECTRIC ASSOCIATION, AND ADOPTED BY THE UNDERWRITERS' UNIONS OF THE DIFFERENT CITIES OF THE UNITED STATES.

GENERAL SUGGESTIONS.

THE use of wire ways for rendering concealed wiring permanently accessible is most heartily indorsed and recommended, and this method of accessible concealed construction is advised for general use.

Architects are urged, when drawing plans and specifications, to make provision for the channelling and pocketing of buildings for electric light or power wires; and in specifications for electric gas lighting, to require a two-wire circuit, whether the building is to be wired for electric lighting or not, so that no part of the gas fixtures or gas piping be allowed to be used for the gas-lighting circuit.

Wires that are to be concealed will not be approved unless sufficient time is given for this Union to make a complete inspection before the floors are laid, laths put on, or the wires concealed in any other manner.

If notice is sent to the office of the local inspector by the wire contractors when work is begun, there will be no delay in inspecting.

CLASS A.

CENTRAL STATIONS.

FOR LIGHT OR POWER.

These Rules also apply to Dynamo Rooms in Isolated Plants, connected with or detached from buildings used for other purposes: also to all varieties of apparatus therein of both high and low potential.

1. GENERATORS —

a. Must be located in a dry place.

b. Must be insulated on floors or base frames, which must be kept filled, to prevent absorption of moisture, and also kept clean and dry.

c. Must never be placed in a room where any hazardous process is carried on, nor in places where they would be exposed to inflammable gases or flyings or combustible material.

d. Must each be provided with a waterproof covering.

2. CARE AND ATTENDANCE. — A competent man must be kept on duty in the room where generators are operating.

Oily waste must be kept in *approved* metal cans, and removed daily.

Approved waste cans shall be made of metal, with legs raising can three inches from the floor, and with self-closing covers.

3. CONDUCTORS. — From generators, switch-boards, rheostats, or other instruments, and thence to outside lines, conductors —

a. Must be in plain sight, and readily accessible.

b. Must be wholly on non-combustible insulators, such as glass or porcelain.

c. Must be separated from contact with floors, partitions, or walls through which they may pass by non-combustible insulating tubes, such as glass or porcelain.

d. Must be kept rigidly so far apart that they cannot come in contact.

e. Must be covered with non-inflammable insulating material sufficient to prevent accidental contact, except that "bus bars" may be made of bare metal.

f. Must have ample carrying capacity, to prevent heating. (See Capacity of Wires Table.)

4. SWITCH-BOARDS —.

a. Must be so placed as to reduce to a minimum the danger of communicating fire to adjacent combustible material.

Special attention is called to the fact that switch-boards should not be built down to the floor, nor up to the ceiling; but a space of at least eighteen inches, or two feet, should be left between the floor and the board, and between the ceiling and the board, in order to prevent fire from communicating from the switch-board to the floor or ceiling, and also to prevent the forming of a partially concealed space very liable to be used for storage of rubbish and oily waste.

b. Must be accessible from all sides when the connections are on the back; or may be placed against a brick or stone wall when the wiring is entirely on the face.

c. Must be kept free from moisture.

d. Must be made of non-combustible material, or of hard wood in skeleton form, filled to prevent absorption of moisture.

e. Bus bars must be equipped in accordance with Rule 3 for placing conductors.

5. Resistance Boxes and Equalizers —

a. Must be equipped with metal or other non-combustible frames.

The word "frame" in this section relates to the entire case and surrounding of the rheostat, and not alone to the upholding supports.

b. Must be placed on the switch-board, or, if not thereon, at a distance of a foot from combustible material, or separated therefrom by a non-inflammable, non-absorptive, insulating material.

6. Lightning Arresters —

a. Must be attached to each side of every overhead circuit connected with the station.

b. Must be mounted on non-combustible bases in plain sight on the switch-board, or in an equally accessible place, away from combustible material.

c. Must be connected with at least two "earths" by separate wires, not smaller than No. 6 B. & S, which must not be connected to any pipe within the building.

d. Must be so constructed as not to maintain an arc after the discharge has passed.

7. Testing —

a. All series and alternating circuits must be tested every two hours while in operation, to discover any leakage to earth, abnormal in view of the potential and method of operation.

b. All multiple arc low potential systems (300 volts or less) must be provided with an indicating or detecting

device, readily attachable, to afford easy means of testing where the station operates continuously.

c. Data obtained from all tests must be preserved for examination by insurance inspectors.

These rules on testing to be applied at such places as may be designated by the association having jurisdiction.

MOTORS.

8. MOTORS —

a. Must be wired under the same precautions as with a current of the same volume and potential for lighting. The motor and resistance box must be protected by a double pole cut-out, and controlled by a double pole switch.

b. Must be thoroughly insulated, mounted on filled dry wood, be raised at least eight inches above the surrounding floor, be provided with pans to prevent oil from soaking into the floor, and must be kept clean.

c. Must be covered with a waterproof cover when not in use, and, if deemed necessary by the inspector, be enclosed in an *approved* case.

From the nature of the question, the decision as to what is an *approved* case must be left to the inspector to determine in each instance.

9. RESISTANCE BOXES —

a. Must be equipped with metal or other non-combustible frames.

The word "frame" in this section relates to the entire case and surrounding of the rheostat, and not alone to the upholding supports.

b. Must be placed on the switch-board, or at a distance of a foot from combustible material, or separated therefrom by a non-inflammable, non-absorptive, insulating material.

CLASS B.

ARC (SERIES) SYSTEMS.

OVER 300 VOLTS.

Any circuit attached to any machine, or combination of machines, which develops over 300 volts difference of potential between any two wires, shall be considered as a high potential circuit, and coming under that class, unless an *approved* transforming device is used, which cuts the difference of potential down to less than 300 volts.

10. OUTSIDE CONDUCTORS. — All outside overhead conductors (including services) —

a. Must be covered with some *approved* insulating material, not easily abraded, firmly secured to properly insulated and substantially built supports, all tie wires having an insulation equal to that of the conductors they confine.

Insulation that will be *approved* for service wires must be solid, at least $\frac{3}{64}$ of an inch in thickness, and covered with a substantial braid. It must not readily carry fire, must show an insulating resistance of one megohm per mile after two weeks' submersion in water at 70 degrees Fahrenheit, and three days' submersion in lime-water, with a current of 550 volts, and after three minutes' electrification.

b. Must be so placed that moisture cannot form a cross-connection between them, not less than a foot apart, and not in contact with any substance other than their insulating supports.

c. Must be at least seven feet above the highest point of flat roofs, and at least one foot above the ridge of

pitched roofs over which they pass, or to which they are attached.

d. Must be protected by *dead insulated guard irons* or *wires* from possibility of contact with other conducting wires or substances to which current may leak. Special precautions of this kind must be taken where sharp angles occur, or where any wires might possibly come in contact with electric light or power wires.

e. Must be provided with petticoat insulators of glass or porcelain. Porcelain knobs or cleats and rubber hooks will not be approved.

f. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered, to insure preservation, and covered with an insulation equal to that on the conductors.

All joints must be soldered, even if made with the McIntyre or any other patent splicing device. This ruling applies to joints and splices in all classes of wiring covered by these Rules.

11. SERVICE BLOCKS —

a. Must be covered over their entire surface with at least two coats of waterproof paint.

b. Telegraph, telephone, and similar wires must not be placed on the same cross-arm with electric light or power wires.

INTERIOR CONDUCTORS.

12. ALL INTERIOR CONDUCTORS —

a. Must be covered where they enter buildings from outside terminal insulators to and through the walls with extra waterproof insulation, and must have drip loops outside. The hole through which the conductor passes must

be bushed with waterproof and non-combustible insulating tube or hard rubber tube, slanting upward toward the inside. The tube must be sealed with tape, thoroughly painted, and securing the tube to the wire.

b. Must be arranged to enter and leave the building through a double contact service switch, which will effectually close the main circuit and disconnect the interior wires when it is turned "off." The switch must be so constructed that it shall be automatic in its action, not stopping between points when started, and prevent an arc between the points under all circumstances; it must indicate on inspection whether the current be "on" or "off," and be mounted in a non-combustible case, and kept free from moisture and easy of access to police or firemen.

c. Must be always in plain sight, and never encased, except when *required* by the inspector.

d. Must be covered in all cases with an *approved* non-combustible material that will adhere to the wire, not fray by friction, and bear a temperature of 150 degrees Fahrenheit without softening.

Insulation that will be *approved* for interior conductors must be solid, at least $\frac{3}{64}$ of an inch in thickness, and covered with a substantial braid. It must not readily carry fire, must show an insulating resistance of one megohm per mile after two weeks' submersion in water at 70 degrees Fahrenheit, and three days' submersion in lime-water, with a current of 550 volts, and after three minutes' electrification.

e. Must be supported on glass or porcelain insulators, and kept rigidly at least eight inches from each other, except within the structure of lamps, or on hanger boards, cut-out boxes, or the like, where less distance is necessary.

f. Must be separated from contact with walls, floors, timbers, or partitions through which they may pass by non-combustible insulating tube or hard rubber tube.

g. Must be so spliced or joined as to be both mechanically and electrically secure without solder. They must then be soldered to insure preservation, and covered with an insulation equal to that on the conductors.

LAMPS AND OTHER DEVICES.

13. ARC LAMPS — In every case —

a. Must be carefully isolated from inflammable material.

b. Must be provided at all times with a glass globe surrounding the arc, securely fastened upon a closed base. No broken or cracked globes to be used.

c. Must be provided with an *approved* hand switch, also an automatic switch, that will shunt the current around the carbons should they fail to feed properly.

The hand switch to be *approved*, if placed anywhere except on the lamp itself, must comply with requirements for switches on hanger boards as laid down in Section (*g*).

d. Must be provided with reliable stops to prevent carbons from falling out in case the clamps become loose.

e. Must be carefully insulated from the circuit in all their exposed parts.

f. Must be provided with a wire netting around the globe, and an *approved* spark arrester above, to prevent escape of sparks, melted copper or carbon, where readily inflammable material is in the vicinity of the lamps. It is recommended that plain carbons, not copper plated, be used for lamps in such places.

An *approved* spark arrester is one which will so close

tbe upper orifice of the globe, that it will be impossible fo any sparks thrown off by the carbons to escape.

g. Hanger boards must be so constructed that all wire and current-carrying devices thereon shall be exposed t view, and thoroughly insulated by being mounted on waterproof, non-combustible substance. All switche attached to the same must be so constructed that the shall be automatic in their action, not stopping betwee points when started, and preventing an arc between point under all circumstances.

14. INCANDESCENT LAMPS IN SERIES CIRCUITS HAVIN A MAXIMUM POTENTIAL OF 300 VOLTS OR OVER —

a. Must be governed by the same rules as for arc lights, and each series lamp provided with an *approved* hand-spring switch and automatic cut-out.

b. Must have each lamp suspended from a hange board by means of a rigid tube.

c. No electro-magnetic device for switches, and no system of multiple-series or series-multiple lighting will be approved.

d. Under no circumstances can series lamps be attached to gas fixtures.

CLASS C.

INCANDESCENT (LOW PRESSURE) SYSTEMS.

300 VOLTS OR LESS.

OUTSIDE CONDUCTORS.

15. OUTSIDE OVERHEAD CONDUCTORS —

a. Must be erected in accordance with the rules for arc (series) circuit conductors.

b. Must be separated not less than 12 inches, and be

provided with an *approved* fusible cut-out that will cut off the entire current as near as possible to the entrance to the building and inside the walls.

An *approved* fusible cut-out must comply with the sections of Rules 23 and 24 describing fuses and cut-outs.

The cut-out required by this section must be placed so as to protect the switch required by Rule 17.

16. UNDERGROUND CONDUCTORS —

a. Must be protected against moisture and mechanical injury, and be removed at least two feet from combustible material when brought into a building, but not connected with the interior conductors.

b. Must have a switch and a cut-out for each wire between the underground conductors and the interior wiring when the two parts of the wiring are connected.

These switches and fuses must be placed as near as possible to the end of the underground conduit, and connected therewith by specially insulated conductors, kept apart not less than two and a half inches.

The cut-out required by this section must be placed so as to protect the switch.

c. Must not be so arranged as to shunt the current through a building around any catch-box.

INSIDE WIRING.

GENERAL RULES.

17. — At the entrance of every building there shall be an *approved* switch placed in the service conductors by which the current may be entirely cut off.

The switch required by this rule to be *approved* must be double pole, must plainly indicate whether the current

is "on" or "off," and must comply with Sections *a*, *c*, *d*, and *e* of Rule 26 relating to switches.

18. CONDUCTORS —

a. Must have an *approved* insulating covering, and must not be of sizes smaller than No. 14 B. & S.; No. 16 B. W. G., or No. 4 E. S. G., except that, in conduit installed under Rule 22, No. 16 B. & S., No. 18 B. W. G., or No. 4 E. S. G., may be used.

In so-called "concealed" wiring, moulding, and conduit work, *and* in places liable to be exposed to dampness, the insulating covering of the wire, to be *approved*, must be solid, at least $\frac{3}{64}$ of an inch in thickness, and covered with a substantial braid. It must not readily carry fire, must show an insulating resistance of one megohm per mile after two weeks' submersion in water at 70 degrees Fahrenheit, and three days' submersion in lime-water, with a current of 550 volts, and after three minutes' electrification.

For work which is *entirely* exposed to view throughout the whole interior circuits, and not liable to be exposed to dampness, a wire with an insulating covering that will not support combustion, will resist abrasion, is at least $\frac{1}{16}$ of an inch in thickness, and thoroughly impregnated with a moisture repellent, will be *approved*.

b. Must be protected when passing through floors, or through walls, partitions, timbers, etc., in places liable to be exposed to dampness, by waterproof, non-combustible, insulating tubes, such as glass or porcelain.

Must be protected when passing through walls, partitions, timbers, etc., in places not liable to be exposed to dampness, by *approved* insulating bushings especially made for the purpose.

Except for FLOORS, *and* for places liable to be exposed

to dampness, glass, porcelain, *metal-sheathed* interior conduit, and vulca tube, when made especially for bushings, will be *approved.* **The two last named will not be approved if cut from the usual lengths of tube made for conduit work, nor when made without a head or flange on one end.**

c. Must be kept free from contact with gas, water, or other metallic piping, or any other conductors or conducting material which they may cross (except high potential conductors), by some continuous and firmly fixed non-conductor creating a separation of at least one inch. Deviations from this rule may sometimes be allowed by special permission.

d. Must be so placed in crossing high potential conductors that there shall be a space of at least one foot at all points between the high and low tension conductors.

e. Must be so placed in wet places, that an air space will be left between conductors and pipes in crossing, and the former must be run in such a way that they cannot come in contact with the pipe accidentally. Wires should be run *over* all pipes upon which condensed moisture is likely to gather, or which by leaking might cause trouble on a circuit.

SPECIAL RULES.

19. WIRING NOT ENCASED IN MOULDING OR APPROVED CONDUIT —

a. Must be supported wholly on non-combustible insulators, constructed so as to prevent the insulating coverings of the wire from coming in contact with other substances than the insulating supports.

b. Must be so arranged that wires of opposite polarity, with a difference of potential of 150 volts or less, will be kept apart at least two and one-half inches.

c. Must have the above distance increased proportionately where a higher voltage is used, unless they are encased in moulding or approved conduit.

d. Must not be laid in plaster, cement, or similar finish.

e. Must never be fastened with staples.

In Unfinished Lofts, between Floor and Ceilings, in Partitions and other Concealed Places—

f. Must have at least one inch clear air space surrounding them.

g. Must be at least ten inches apart when possible, and should be run singly on separate timbers or studding.

h. Wires run as above immediately under roofs, in proximity to water tanks or pipes, will be considered as exposed to moisture.

i. Wires must not be fished for any great distance, and only in places where the inspector can satisfy himself that the above rules have been complied with.

j. Twin wires must never be employed in this class of concealed work.

20. Mouldings—

a. Must never be used in concealed work or in damp places.

b. Must have at least two coats of waterproof paint, or be impregnated with a moisture repellent.

c. Must be made of two pieces, a backing and capping, so constructed as to thoroughly encase the wire, and maintain a distance of one-half inch between conductors of opposite polarity, and afford suitable protection from abrasion.

21. SPECIAL WIRING —

In breweries, packing-houses, stables, dyehouses, paper and pulp mills, or other buildings specially liable to moisture or acid, or other fumes liable to injure the wires or insulation, except where used for pendants, conductors —

a. Must be separated at least six inches.

b. Must be provided with an approved waterproof covering.

The insulating covering of the wire to be *approved* under this section must be solid, at least $\frac{3}{64}$ of an inch in thickness, and covered with a substantial braid. It must not readily carry fire, must show an insulating resistance of one megohm per mile after two weeks' submersion in water at 70 degrees Fahrenheit, and three days' submersion in lime-water, with a current of 550 volts, after three minutes' electrification, and must *also* withstand a satisfactory test against such chemical compounds or mixtures as it will be liable to be subjected to in the risk under consideration.

c. Must be carefully put up.

d. Must be supported by glass or porcelain insulators. No switches or fusible cut-outs will be allowed where exposed to inflammable gases or dust, or to flyings of combustible material.

e. Must be protected when passing through floors, walls, partitions, timbers, etc., by waterproof non-combustible, insulating tubes, such as glass or porcelain.

22. INTERIOR CONDUITS[1] —

a. Must be continuous from one junction box to another, or to fixtures, and must be of material that will

[1] The object of a tube or conduit is to facilitate the insertion or extraction of the conductors, to protect them from mechanical injury, and, as far

resist the fusion of the wire or wires they contain, without igniting the conduit. The American Circular Loom Co. Tube, the *metal-sheathed* Interior Conduit Tube, and the Vulca Tube are approved for the class of work called for in this rule.

b. Must not be of such material or construction that the insulation of the conductor will ultimately be injured or destroyed by the elements of the composition.

c. Must be first installed as a complete conduit system, without conductors, strings, or anything for the purpose of drawing in the conductors, and the conductors then to be pushed or fished in. The conductors must not be placed in position until all mechanical work on the building has been, as far as possible, completed.

d. Must not be so placed as to be subject to mechanical injury by saws, chisels, or nails.

e. Must not be supplied with a twin conductor, or two separate conductors, in a single tube.

f. *Must have all ends closed* with good adhesive material, either at junction boxes or elsewhere, whether such ends are concealed or exposed. Joints must be made air-tight and moisture-proof.

g. Conduits must extend at least one inch beyond the finished surface of walls or ceilings until the mortar or other similar material be entirely dry, when the projection may be reduced to half an inch.

23. Double Pole Safety Cut-outs—

a. Must be in plain sight, or enclosed in an *approved* box, readily accessible. To be *approved*, boxes must be

as possible, from moisture. Tubes or conduits are to be considered merely as raceways, and are not to be relied on for insulation between wire and wire, or between the wire and the ground.

constructed, and cut-outs arranged, whether in a box or not, so as to obviate any danger of the melted fuse metal coming in contact with any substance which might be ignited thereby.

b. Must be placed at every point where a change is made in the size of the wire (unless the cut-out in the larger wire will protect the smaller).

c. Must be supported on bases of non-combustible, insulating, moisture-proof material.

d. Must be supplied with a plug (or other device for enclosing the fusible strip or wire) made of incombustible and moisture-proof material, and so constructed that an arc cannot be maintained across its terminals by the fusing of the metal.

e. Must be so placed that on any combination fixture no group of lamps requiring a current of six amperes or more shall be ultimately dependent upon one cut-out. Special permission may be given *in writing* by the inspector for departure from this rule in case of large chandeliers.

f. All cut-out blocks must be stamped with their *maximum* safe carrying capacity in amperes, and *when installed* must be marked with the current they are intended to carry.

24. Safety Fuses —

a. Must all be stamped or otherwise marked with the number of amperes they will carry indefinitely without melting.

b. Must have fusible wires or strips (where the plug or equivalent device is not used), with contact surfaces or tips of harder metal, soldered or otherwise, having perfect electrical connection with the fusible part of the

strip, whenever they have a carrying of ten (10) amperes or over.

c. Must all be so proportioned to the conductors they are intended to protect, that they will melt before the maximum safe carrying capacity of the wire is exceeded.

25. TABLE OF CAPACITY OF WIRES —

It must be clearly understood that the size of the fuse depends upon the size of the smallest conductor it protects, and not upon the amount of current to be used on the circuit. Below is a table showing the safe carrying capacity of conductors of different sizes in Birmingham, Brown & Sharpe, and Edison gauges, which must be followed in the placing of interior conductors : —

BROWN & SHARPE.		BIRMINGHAM.		EDISON STANDARD.	
Gauge No.	Amperes.	Gauge No.	Amperes.	Gauge No.	Amperes.
0000	175	0000	175	200	175
000	145	000	150	180	160
00	120	00	130	140	135
0	100	0	110	110	110
1	95	1	95	90	95
2	70	2	85	80	85
3	60	3	75	65	75
4	50	4	65	55	65
5	45	5	60	50	60
6	35	6	50	40	50
7	30	7	45	30	40
8	25	8	35	25	35
10	20	10	30	20	30
12	15	12	20	12	20
14	10	14	15	8	15
16	5	16	10	5	10
18	3	18	5	3	5
		20	3	2	3

26. SWITCHES —

a. Must be mounted on moisture-proof and non-combustible bases, such as slate or porcelain.

b. Must be double pole when the circuits which they

control supply more than six 16 candle power lamps, or their equivalent.

c. Must have a firm and secure contact, must make and break readily, and not stop when motion has once been imparted by the handle.

d. Must have carrying capacity sufficient to prevent heating.

e. Must be placed in dry, accessible places, and be grouped as far as possible, being mounted — when practicable — upon slate or equally non-combustible back boards. Jackknife switches, whether provided with friction or spring stops, must be so placed that gravity will tend to open rather than close the switch.

27. Fixture Work —

a. In all cases where conductors are concealed within or attached to gas fixtures, the latter must be insulated from the gas-pipe system of the building by means of approved joints. The insulating material used in such joints must be of a substance not affected by gas and that will not shrink or crack by variation in temperature. Insulating joints with soft rubber in their construction will not be approved.

Insulating joints, to be *approved*, must be entirely made of material that will resist the action of illuminating gases, and will not give way or soften under the heat of an ordinary gas flame. They shall be so arranged that a deposit of moisture will not destroy the insulating effect, and shall have an insulating resistance of 250,000 ohms between the gas-pipe attachments, and be sufficiently strong to resist the strain they will be liable to in attachment.

b. Supply conductors, and especially the splices to fix-

ture wires, must be kept clear of the grounded part of gas-pipes; and where shells are used, the latter must be constructed in a manner affording sufficient area to allow this requirement.

c. When fixtures are wired outside, the conductors must be so secured as not to be cut or abraded by the pressure of the fastenings or motion of the fixture.

d. All conductors for fixture work must have a water-proof insulation that is durable and not easily abraded, and must not in any case be smaller than No. 18 B. & S., No. 20 B. W. G., No. 2 E. S. G.

e. All burrs or fins must be removed before the conductors are drawn into a fixture.

f. The tendency to condensation within the pipes should be guarded against by sealing the upper end of the fixture.

g. No combination fixture in which the conductors are concealed in a space less than one-fourth inch between the inside pipe and the outside casing will be approved.

h. Each fixture must be tested for "contacts" between conductors and fixtures, for "short circuits," and for ground connections before the fixture is connected to its supply conductors.

i. Ceiling blocks of fixtures should be made of insulating material; if not, the wires in passing through the plate must be surrounded with hard rubber tubing.

28. Arc Lights on Low Potential Circuits—

a. Must be supplied by branch conductors not smaller than No. 12 B. & S. gauge.

b. Must be connected with main conductors only through double pole cut-outs.

c. Must only be furnished with such resistances or regulators as are enclosed in non-combustible material, such resistances being treated as stoves.

Incandescent lamps must not be used for resistance devices.

d. Must be supplied with globes and protected as in the case of arc lights on high potential circuits.

29. Electric Gas Lighting.

Where electric gas lighting is to be used on the same fixture with the electric light —

a. No part of the gas piping or fixture shall be in electrical connection with the gas-lighting circuit.

b. The wires used with the fixtures must have a non-inflammable insulation, or, where concealed between the pipe and shell of the fixture, the insulation must be such as required for fixture wiring for the electric light.

c. The whole installation must test free from "grounds."

d. The two installations must test perfectly free from connection with each other.

30. Sockets —

a. No portion of the lamp socket exposed to contact with outside objects must be allowed to come into electrical contact with either of the conductors.

b. In rooms where inflammable gases may exist, or where the atmosphere is damp, the incandescent lamp and socket should be enclosed in a vapor-tight globe.

31. Flexible Cord —

a. Must be made of conductors, each surrounded with a moisture-proof and a non-inflammable layer, and further insulated from each other by a mechanical separa-

tor of carbonizable material. Each of these conductors must be composed of several strands.

b. Must not sustain more than one light not exceeding 50 candle power.

c. Must not be used, except for pendants, wiring of fixtures, and portable lamps or motors.

d. Must not be used in show windows.

e. Must be protected by insulating bushings where the cord enters the socket. The ends of the cord must be taped to prevent fraying of the covering.

f. Must be so suspended that the entire weight of the socket and lamp will be borne by knots under the bushing in the socket, and above the point where the cord comes through the ceiling block or rosette, in order that the strain may be taken from the joints and binding-screws.

g. Must be equipped with keyless sockets as far as practicable, and be controlled by wall switches.

CLASS D.

ALTERNATING SYSTEMS. — CONVERTERS OR TRANSFORMERS.

32. CONVERTERS —

a. Must not be placed inside of any building, except the central station, unless by special permission of the underwriters having jurisdiction.

b. Must not be placed in any but metallic or other non-conbustible cases.

c. Must not be attached to the outside walls of buildings, unless separated therefrom by substantial insulating supports.

IN THOSE CASES WHERE IT MAY NOT BE POSSIBLE TO EXCLUDE THE CONVERTERS AND PRIMARY WIRES ENTIRELY FROM THE BUILDING, THE FOLLOWING PRECAUTIONS MUST BE STRICTLY OBSERVED: —

33. CONVERTERS —

Converters must be located at a point as near as possible to that at which the primary wires enter the building, and must be placed in a room or vault constructed of, or lined with, fire-resisting material, and used only for the purpose. They must be effectually insulated from the ground, and the room in which they are placed be practically air-tight, except that it shall be thoroughly ventilated to the outdoor air, if possible, through a chimney or flue.

34. PRIMARY CONDUCTORS —

a. Must each be heavily insulated with a coating of moisture-proof material from the point of entrance to the transformer, and, in addition, must be so covered and protected that mechanical injury to them or contact with them shall be practically impossible.

b. Must each be furnished, if within a building, with a switch and a fusible cut-out where the wires enter the building, or where they leave the main line, on the pole or in the conduit. These switches should be enclosed in secure and fireproof boxes, preferably outside the building.

c. Must be kept apart at least ten inches, and at the same distance from all other conducting bodies when inside a building.

35. SECONDARY CONDUCTORS —

a. Must be installed according to the rules for "Low Potential Systems."

CLASS E.

ELECTRIC RAILWAYS.

36. — All rules pertaining to arc light wires and stations shall apply (so far as possible) to street railway power stations and their conductors in connection with them.

37. Power Stations —

a. Must be equipped in each circuit as it leaves the station with an approved automatic "breaker" or other device that will immediately cut off the current in case the trolley wires become grounded. This device must be mounted on a fireproof base and in full view and reach of the attendant.

Automatic circuit breakers should be submitted for *approval* before being used.

38. Trolley Wires —

a. Must be no smaller than No. 0, B. & S. copper or No. 4, B. & S. silicon bronze, and must readily stand the strain put upon them when in use.

b. Must be well insulated from their supports, and, in case of the side or double pole construction, the supports shall also be insulated from the poles immediately outside of the trolley-wire.

c. Must be capable of being disconnected at the power house, or of being divided into sections, so that, in case of fire on the railway route, the current may be shut off from the particular section, and not interfere with the work of the firemen. This rule also applies to *feeders*.

d. Must be safely protected against contact with all other conductors.

39. CAR WIRING —

a. Must be always run out of reach of the passengers, and must be insulated with a waterproof insulation.

40. LIGHTING AND POWER FROM RAILWAY WIRES —

a. Must not be permitted under any pretence in the same circuit with trolly wires with a ground return, nor shall the same dynamo be used for both purposes, except in street railway cars, electric car houses, and their power stations.

41. CAR HOUSES —

Must have special cut-outs located at a proper distance outside, so that all circuits within any car house can be cut out at one point.

42. GROUND RETURN WIRES —

Where ground return is used it must be so arranged that no difference of potential will exist greater than five volts to 50 feet, or 50 volts to the mile between any two points in the earth or pipes therein.

CLASS F.

43. STORAGE OR PRIMARY BATTERIES —

a. When current for light and power is taken from primary or secondary batteries the same general regulations must be observed as apply to similar apparatus fed from dynamo generators developing the same difference of potential.

b. All secondary batteries must be mounted on *approved* insulators.

Insulators for mounting secondary batteries to be *approved* must be non-combustible, such as glass, or thoroughly vitrified and glazed porcelain,

c. Special attention is directed to the rules for rooms where acid fumes exist.

d. The use of any metal liable to corrosion must be avoided in connections of secondary batteries.

MISCELLANEOUS.

44. — *a*. The wiring in any building must test free from grounds; i.e., each main supply line and every branch circuit shall have an insulation resistance of at least 25,000 ohms, and should have an insulation resistance between conductors and between all conductors and the ground (not including attachments, sockets, receptacles, etc.) of not less than the following : —

Up to	10	amperes	4,000,000
"	25	"	1,600,000
"	50	"	800,000
"	100	"	300,000
"	200	"	160,000
"	400	"	80,000
"	800	"	22,000
"	1,600	"	11,000

All cut-outs and safety devices in place in the above.

Where lamp sockets, receptacles, and electroliers, etc., are connected, one half of the above will be required.

b. Ground wires for lightning arresters of all classes and ground detectors must not be attached to gas pipes within the building.

c. Where telephone, telegraph, or other wires connected with outside circuits are bunched together within any building, or where inside wires are laid in conduit or duct with electric light or power wires, the covering of such wires must be fire-resisting, or else the wires must be enclosed in an air-tight tube or duct,

d. All conductors connecting with telephone, district messenger, burglar alarm, watch clock, electric time, and other similar instruments, must be provided near the point of entrance to the building with some protective device which will operate to shunt the instruments in case of a dangerous rise of potential, and will open the circuit and arrest an abnormal current flow. Any conductor normally forming an innocuous circuit may become a source of fire hazard if crossed with another conductor, through which it may become charged with a relatively high pressure.

e. The following formula for soldering fluid is suggested: —

Saturated solution of zinc	5 parts.
Alcohol	4 parts.
Glycerine	1 part.

MATERIALS: —

The following are given as a list of NON-COMBUSTIBLE, NON-ABSORPTIVE, INSULATING materials, and are listed here for the benefit of those who might consider hard rubber, fibre, wood, and the like, as fulfilling the above requirements. Any other substance which it is claimed should be accepted, must be forewarded for testing before being put on the market: —

1. Thoroughly vitrified and glazed Porcelain.
2. Glass.
3. Slate without metal veins.
4. Pure Sheet Mica.
5. Marble (filled).
6. Lava (certain kinds of).
7. Alberene Stone.

INSULATING JOINTS: —

The mica joints of the following makes are approved: —

E. P. Gleason Manufacturing Co., New York.
W. T. C. Macallen Co., Boston.
Thackara Manufacturing Co., Philadelphia.

WIRES: —

The following list of wires have been tested, and found to comply with the requirements for an approved insulation under Rule 10 (*a*), Rule 12 (*d*), and Rule 18 (*a*).

Americanite.
Bishop.
Canvasite.
Clark.
Columbia.
Crescent.
Crown.
Edison Machine.
Grimshaw (white core).
Habirshaw (red core).
Kerite.
National India Rubber Co. (N. I. R).
Okonite.
Paranite.
Raven Core.
Safety Insulated { Requa white core. / Safety black core. }
Salamander (rubber covered).
Simplex (caoutchouc).

None of the above wires to be used unless protected with a substantial *braided* outer covering.

TABLE OF DIMENSIONS AND RESISTANCES OF PURE COPPER WIRE.*

REVISED.

No. B. & S.	Diam. Mils.	Area		W'gt. & Length. Sp. gr. 8.9.			No. B. & S.	Resistance at 75° F.				Lbs. per 1000 ft. ins'd H. B. & H line wire.	Ft. per lb. ins'd H. B. & H line wire.
		Circular Mils.	Square Inches.	Lbs. per 1000 ft.	Pounds per Mile.	Feet per Pound.		R Ohms per 1000 feet.	Ohms per mile.	Feet per Ohm.	Ohms per Pound.		
0000	460.000	211600.0	166190.2	640.73	3383.04	1.56	4–0	.04904	.25891	20392.9	.00007653	800	1.25
000	409.640	167805.0	131793.7	508.12	2682.85	1.97	3–0	.06184	.32649	16172.1	.00012169	666	1.50
00	364.800	133079.0	104520.0	402.97	2127.66	2.48	00	.07797	.41168	12825.4	.00019438	500	2.00
0	324.950	105592.5	82932.2	319.74	1688.20	3.13	0	.09827	.51885	10176.4	.00030734	363	2.75
1	289.300	83694.5	65733.5	253.43	1338.10	3.95	1	.12398	.65460	8066.0	.00048920	313	3.20
2	257.630	66373.2	52129.4	200.98	1061.17	4.98	2	.15633	.82543	6396.7	.00077784	250	4.00
3	229.420	52633.5	41338.3	159.38	841.50	6.28	3	.19714	1.04090	5072.5	.0012370	200	5.00
4	204.310	41742.6	32784.5	126.40	667.38	7.91	4	.24858	1.31248	4022.9	.0019666	144	6.9
5	181.940	33102.2	25998.4	100.23	529.23	9.98	5	.31346	1.65507	3190.2	.0031273	125	8.0
6	162.020	26250.5	20617.1	79.49	419.69	12.58	6	.39528	2.08706	2529.9	.0049728	105	9.5
7	144.280	20816.7	16349.4	63.03	332.82	15.86	7	.49845	2.63184	2006.2	.0079078	87	11.5
8	128.490	16509.7	12966.7	49.99	263.96	20.00	8	.62849	3.31843	1591.1	.0125719	69	14.5
9	114.430	13094.2	10284.2	39.65	209.35	25.22	9	.79242	4.18400	1262.0	.0199853		
10	101.890	10381.6	8153.67	31.44	165.98	31.81	10	.99948	5.27726	1000.5	.0317046	50	20.0
11	90.742	8234.11	6467.06	24.93	131.65	40.11	11	1.2602	6.65357	793.56	.0505413		
12	80.808	6529.94	5128.60	19.77	104.40	50.58	12	1.5890	8.39001	629.32	.0803641	31	32.0
13	71.961	5178.39	4067.09	15.68	82.792	63.78	13	2.0037	10.5798	499.06	.127788		
14	64.084	4106.76	3225.44	12.44	65.658	80.42	14	2.5266	13.3405	395.79	.203180	22	45.0
15	57.068	3256.76	2557.85	9.86	52.069	101.40	15	3.1860	16.8223	313.87	.323079		
16	50.820	2582.67	2028.43	7.82	41.292	127.87	16	4.0176	21.2130	248.90	.513737	14	70.0
17	45.257	2048.20	1608.65	6.20	32.746	161.24	17	5.0660	26.7485	197.39	.816839		
18	40.303	1624.33	1275.75	4.92	25.970	203.31	18	6.3880	33.7285	156.54	1.298764	11	90.0
19	35.890	1288.09	1011.66	3.90	20.594	256.39	19	8.0555	42.5329	124.14	2.065312		
20	31.961	1021.44	802.24	3.09	16.331	323.32	20	10.1584	53.6362	98.44	3.284374		
21	28.462	810.09	636.24	2.45	12.952	407.67	21	12.8088	67.6302	78.07	5.221775		
22	25.347	642.47	504.60	1.95	10.272	514.03	22	16.1504	85.2743	61.92	8.301819		
23	22.571	509.45	400.12	1.54	8.1450	648.25	23	20.3674	107.540	49.10	13.20312		
24	20.100	404.01	317.31	1.22	6.4593	817.43	24	25.6830	135.606	38.94	20.99405		
25	17.900	320.41	251.65	.97	5.1227	1030.71	25	32.3833	170.984	30.88	33.37780		
26	15.940	254.08	199.56	.77	4.0623	1299.77	26	40.8377	215.623	24.49	53.07946		
27	14.195	201.50	158.26	.61	3.2215	1638.97	27	51.4952	271.895	19.42	84.39916		
28	12.641	159.80	125.50	.48	2.5548	2066.71	28	64.9344	342.854	15.40	134.2005		
29	11.257	126.72	99.526	.38	2.0260	2606.13	29	81.8827	432.341	12.21	213.3973		
30	10.025	100.50	78.933	.30	1.6068	3286.04	30	103.245	545.133	9.686	339.2673		
31	8.928	79.71	62.603	.24	1.2744	4143.18	31	130.176	687.327	7.682	539.3404		
32	7.950	63.20	49.639	.19	1.0105	5225.26	32	164.174	866.837	6.091	857.8498		
33	7.080	50.13	39.369	.15	.8014	6588.33	33	207.000	1092.96	4.831	1363.786		
34	6.304	39.74	31.212	.12	.6354	8310.17	34	261.099	1378.60	3.830	2169.776		
35	5.614	31.52	24.753	.10	.5039	10478.46	35	329.225	1738.31	3.037	3449.770		
36	5.000	25.00	19.635	.08	.3997	13209.98	36	415.047	2191.45	2.409	5482.766		
37	4.453	19.83	15.574	.06	.3170	16654.70	37	523.278	2762.91	1.911	8715.030		
38	3.965	15.72	12.347	.05	.2513	21006.60	38	660.011	3484.86	1.515	13864.51		
39	3.531	12.47	9.7923	.04	.1993	26487.84	39	832.228	4394.16	1.202	22043.92		
40	3.144	9.88	7.7635	.03	.1580	33410.05	40	1049.718	5542.51	.9526	35071.11		

* 1 mile pure copper wire 1-16 in. diam. = 13.59 ohms at 15.5°C or 59.9°F.

THE MASON REDUCING VALVE.

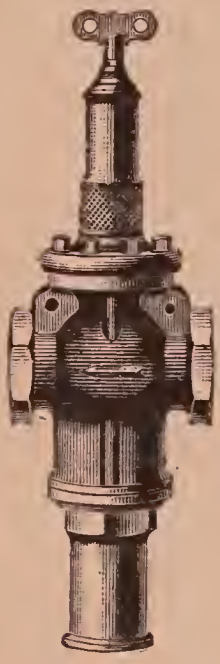
This valve is designed to reduce and maintain an even steam or air pressure regardless of the initial pressure. It will automatically reduce boiler pressure for steam-heating coils, dry rooms, paper-making machinery, slashers, dye kettles, and all places where it is desirable to use lower pressure than that of the boiler. The dash-pot, which immediately fills with condensation, prevents all chattering or pounding, and requires no attention. No extra lock-up attachment is needed, as the pressure is regulated by a key, which the engineer retains. The sizes, up to and including 2-inch, are made of the best composition, and above that, of cast iron, with composition linings. In the larger sizes, the composition lining is hung up in the valve, leaving a space between the iron and composition for the unequal expansion of the metals. Thus there is no possibility of the piston sticking when the valve is heated. The area of the passage from the high to the low pressure side of the valve is equal, when open, to the full area of the pipe, so that a low pressure of the system, almost equal to the initial high pressure, may be carried. This valve will maintain an even steam or air pressure as low as one pound if necessary. This valve is warranted to do all that is claimed for it, and will be sent to responsible parties on 30 days' trial. We make an iron valve for use with ammonia in ice-making machinery.

PRICE LIST.

SIZE PIPE.	PRICE.
½ inch	$15.00
¾ "	18.00
1 "	22.00
1¼ "	28.00
1½ "	35.00
2 "	44.00
2½ "	57.00
3 "	72.00
4 "	100.00
5 "	135.00
6 "	180.00
8 "	250.00

Manufactured by the MASON REGULATOR CO., Boston, Mass.

THE MASON PUMP PRESSURE REGULATOR.



For Fire, Tank, Elevator, Air and Water Works Pumps, or any class of Pumping Machinery where it is necessary to maintain a constant pressure. The Mason Pressure Regulator is made upon an entirely new principle, the advantage of which is that the steam itself is made both to open and shut the valve. The Regulator may be instantly adjusted to any pressure desired by simply turning the key, as shown in the cut.

The especial feature of this regulator is that the pressure chamber into which the water enters is entirely removed and separate from the steam and all working parts.

The long cylinder at the bottom of the regulator is a dash-pot, the piston of which is connected with the main valve of regulator, thereby preventing sudden and violent "jumping" of the pump when the pressure suddenly changes.

For automatic fire sprinkler service they have been fou: d especially valuable, as the valve is thrown wide open, immediately the slightest drop in pressure occurs. On application we can refer parties where they are in use.

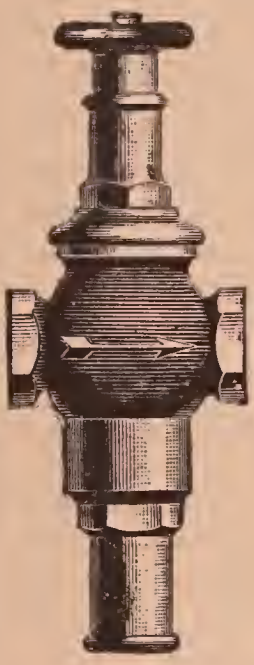
These regulators are made in all the pipe sizes; those up to and including 2-inch, of the best steam metal; the larger sizes, of cast iron, lined with steam metal. The springs are made of the finest tool steel, tempered.

PRICE LIST.

SIZE PIPE.	PRICE.
½ inch	$17.00
¾ "	20.00
1 "	25.00
1¼ "	30 00
1½ "	42.00
2 "	55.00
2½ "	68.00
3 "	85.00
4 "	115.00

Manufactured by the MASON REGULATOR CO., Boston, Mass.

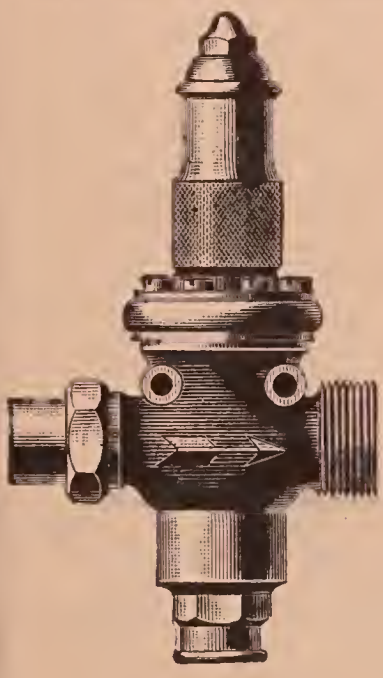
THE MASON LOCOMOTIVE REDUCING VALVE.



This reducing valve has been in use by the leading steam car-heating companies for the last three years. During that time over 3,000 have been placed on nearly every railroad which has adopted steam heat. One feature which will commend itself to every engineer is the self-locking device, which enables the valve to be set for any pressure, and automatically locked. In the manufacture of this valve there is no attempt made to save on stock in order to cheapen the price. Every valve is made of the best steam metal, and will not steam-cut at a pressure of 180 pounds. As we supply a large number of car-heating and railroad companies, each of whom use different connections, we are prepared to furnish the sizes as follows: —

	PRICE.
The ¾ inch size, . . .	$18.00
" 1 " " . . .	22.00
" 1¼ " " . . .	28.00

THE MASON AIR-BRAKE PUMP REGULATOR.



This is constructed on the same principle as our pump pressure regulator, but with a few small changes, so as to allow of its application to air-brake pumps without changing the fittings on the locomotive. It is only necessary to place these in the steam pipe leading to the pump, and connect the air pressure pipe with the train service pipe. As the air chamber is entirely separate from the steam and working parts, any particles of dirt which may get into the main service pipe cannot get into the working parts of the regulator and thence into the pump, neither can the steam and air pressure have access to each other.

We will send one on trial to any railroad. Weight, with couplings, 8½ pounds.

Price, $15 net.

Manufactured by the MASON REGULATOR CO., Boston, Mass.

THE MASON PUMP GOVERNOR.

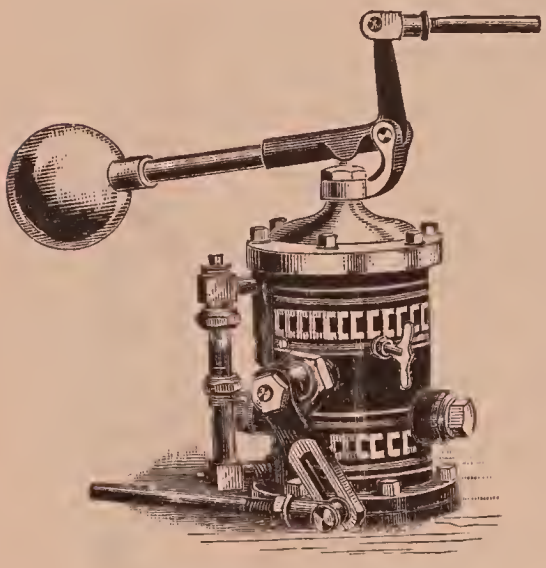


FIG. 1.

The Mason Pump Governor is to the direct acting steam pump what the ordinary ball governor is to the steam engine. It attaches directly to the piston rod of the pump, and operates a balanced valve placed in the steam pipe, thereby exactly weighing the amount of steam to the needs of the pump, and economizing the same. By using the Mason Governor, you can instantly set or change your pump to any required speed, which will be maintained in spite of variation in load or steam pressure. As all the working parts of the Governor are immersed in oil, the wear is reduced to a minimum. It is largely used on vacuum pumps, deep-well pumps, water-works pumps, ice machines, and all classes of pumps requiring a uniform stroke.

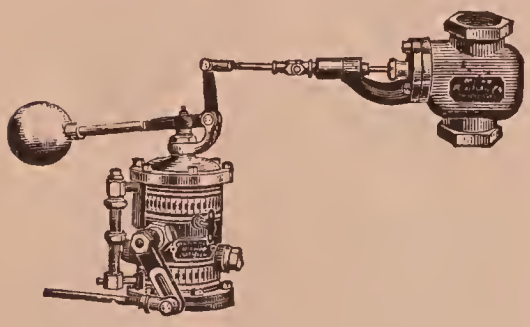


FIG. 2.

For duplex pumps, the Governor is fitted with a special valve, which holds the main piston stationary during the momentary pause of the pump piston, from which the motion is taken.

For large duplex pumping engines a special Governor is made, fitted with double parts, and connected with both piston rods, thus insuring perfect regulation for every portion of each revolution of the engine.

Figure 1 shows the Governor unattached.

Figure 2 shows the Governor connected with balanced valve.

PRICE LIST OF GOVERNOR, WITHOUT VALVE.

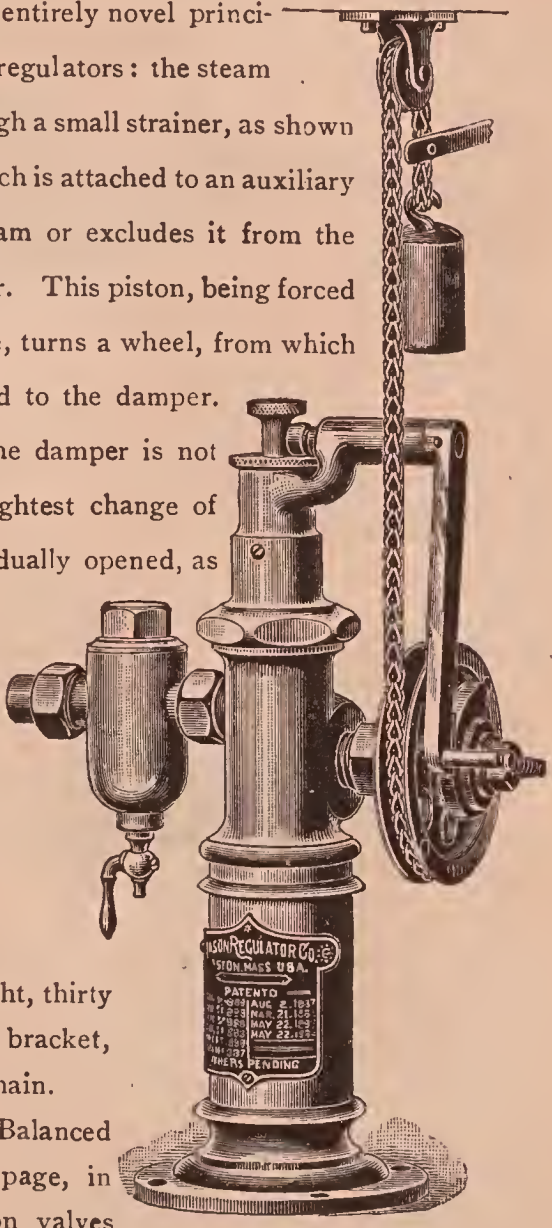
We make three sizes of these Governors: —

	PRICE.
Size No. 1 goes with ½ in. steam valve to 2 in. inc.,	$45.00
" " 2 " " 2½ " " " 4 " "	60.00
" " 3 " " 5 " " " and upward,	80.00

Manufactured by the MASON REGULATOR CO., Boston, Mass.

THE MASON STEAM DAMPER REGULATOR

Is made in accordance with an entirely novel principle in the construction of damper regulators: the steam is admitted from the boiler, through a small strainer, as shown in the cut, under a diaphragm which is attached to an auxiliary valve, which either lets in the steam or excludes it from the piston which works in the cylinder. This piston, being forced up or down by the steam pressure, turns a wheel, from which runs the chain which is connected to the damper. By an ingenious arrangement, the damper is not thrown entirely open by the slightest change of pressure in the boiler, but is gradually opened, as the pressure changes, thereby not allowing sudden and great variations of draft, whereby the coal is wasted.



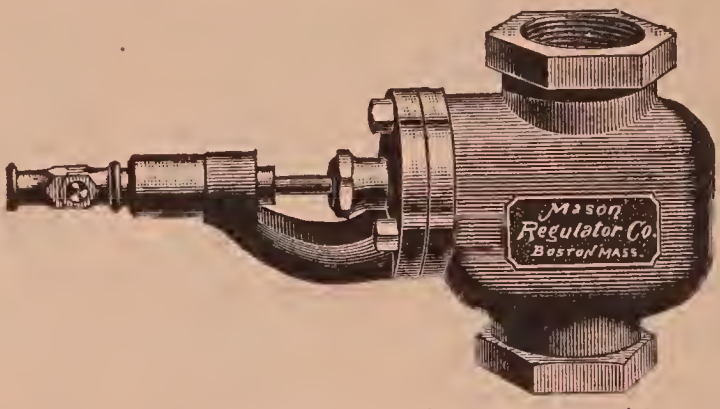
We manufacture only one size. The regulators are made of the best steam metal throughout. Each one is nickel-plated. Weight, thirty pounds. Price, $80, including bracket, weight, and twenty-five feet of chain.

We manufacture our Lever and Balanced Valves, as shown on following page, in two different styles. The piston valves are not perfectly steam tight. The bevel-seated valves are intended for use where it is required for the valve to shut absolutely steam tight.

Style A, Balanced Valve Piston, with straight stem guide.
" B, " " " " " lever attachment.
" C, " " Bevel-seated, with straight stem guide.
" D, " " " " " " lever attachment.

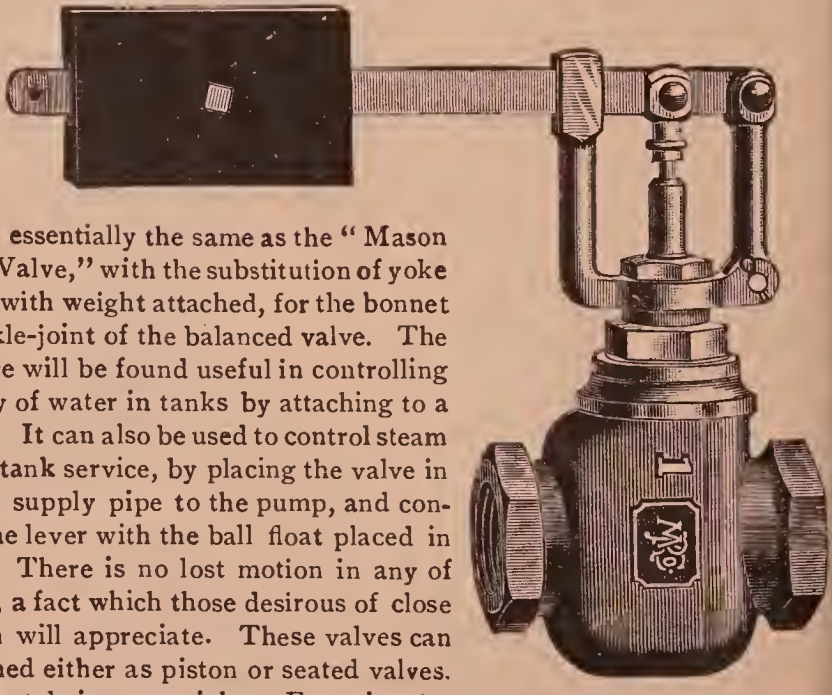
Manufactured by the MASON REGULATOR CO., Boston, Mass.

THE MASON BALANCED VALVE



Is a double piston balanced valve, for use in connection with our speed governor, and for which we have found a ready sale in the many cases where such valves are used. The principal advantage of our valve is in the guide for the valve stem, which is cast on the bonnet, thereby keeping the valve stem in a direct line with the stuffing box. For this reason it is impossible for the valve stem to bend, and the packing seldom has to be renewed. The sizes up to 2-inch are made of the best steam metal; above that, of cast iron, lined with steam metal. A knuckle-joint tapped for three-eighths rod is on the same stem of each valve. This saves expense n making connections.

THE MASON LEVER VALVE



Is made essentially the same as the "Mason Balanced Valve," with the substitution of yoke and lever with weight attached, for the bonnet and knuckle-joint of the balanced valve. The lever valve will be found useful in controlling the supply of water in tanks by attaching to a ball float. It can also be used to control steam pumps in tank service, by placing the valve in the steam supply pipe to the pump, and connecting the lever with the ball float placed in the tank. There is no lost motion in any of the joints, a fact which those desirous of close regulation will appreciate. These valves can be furnished either as piston or seated valves. The latter style is steam tight. For prices, see next page.

Manufactured by the MASON REGULATOR CO., Boston, Mass.

PRICE LIST OF BALANCED AND LEVER VALVES.

SIZE VALVE.	PRICE.
½ inch,	$5.50
¾ "	6.50
1 "	8.00
1¼ "	9.00
1½ "	10.50
2 "	13.00
2½ "	19.50
3 "	25.00
4 "	37.00

CABLE ADDRESS, "MASONICA," BOSTON.

TELEGRAPH CODE.

For quantity of goods wanted use numerals.

Locomotive Reducing Valves,	*Locomotive*
Pump Pressure Regulators,	*Pressure*
Lever Valves,	*Lever*
Pump Governors,	*Governor*
Balanced Valves,	*Balance*
Reducing Valves,	*Reducer*
Damper Regulators,	*Damper*
Air Brake Regulators,	*Brake*

SIZES.

½ inch,	*Madder*
¾ "	*Maggot*
1 "	*Magnate*
1¼ "	*Major*
1½ "	*Malay*
2 "	*Malice*
2½ "	*Mangle*
3 "	*Manly*
4 "	*Marten*
5 "	*Master*
6 "	*Mastic*
8 "	*Mattock*
Ship via Express,	*Worship*
" " Freight,	*Welkin*

Example.— Ship by express five 2-inch reducing valves, "Worship five Malice Reducers."

THE MASON ELEVATOR PUMP PRESSURE REGULATOR.

This is a new pressure regulator, which we have designed especially for elevator pumps, the principal requirement of which is that upon the slightest drop in the water pressure, the pump shall start up to its full capacity. The fulcrum of the lever is a hardened steel knife edge, which makes its action as delicate as a pair of scales. Several large elevator manufacturers are now using these regulators with the best results.

PRICE LIST.

2 inch.	$45.00	3½ inch.	$80.00
2½ "	55.00	4 "	90.00
3 "	70.00		

By a slight change in the interior mechanism, this regulator is made as a by-pass valve for elevator work. Prices same as above.

For moving the rheostat switch on electric elevators, by the variation in water pressure we use the top part of this regulator mounted on a bracket. The rod which connects the regulating device with the steam valve is attached to the electric switch. Price $37.00.

THE MASON VACUUM REGULATING VALVE.

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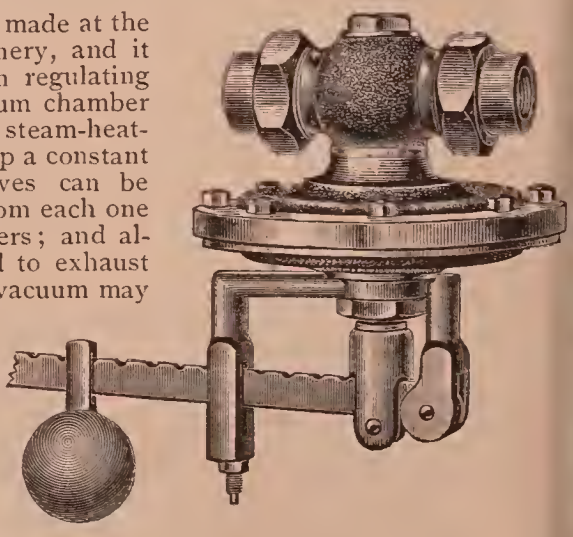

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